The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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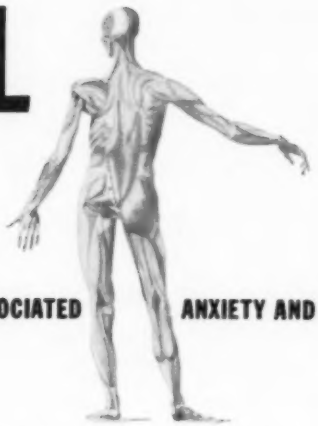

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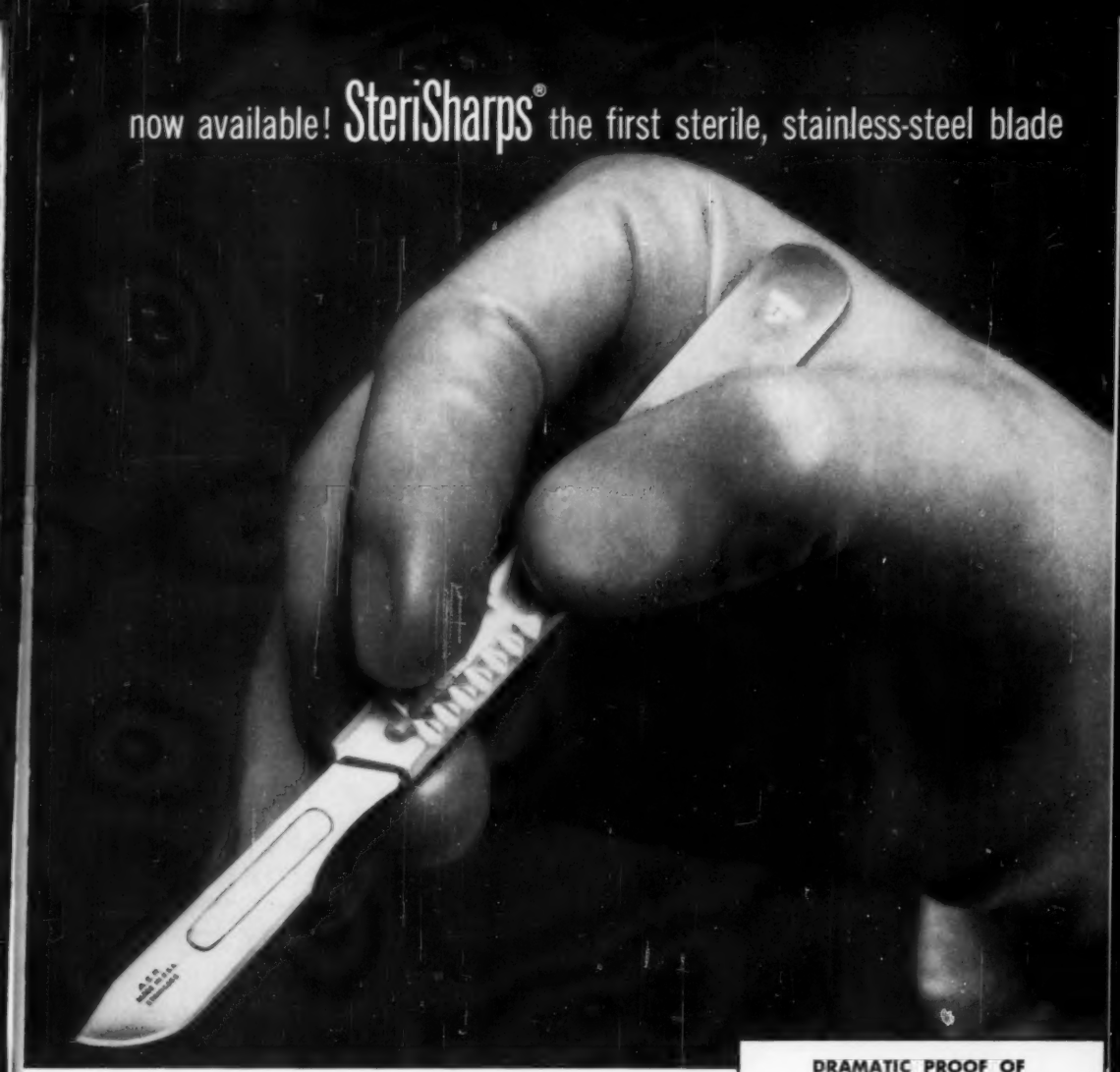

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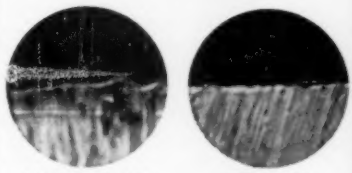

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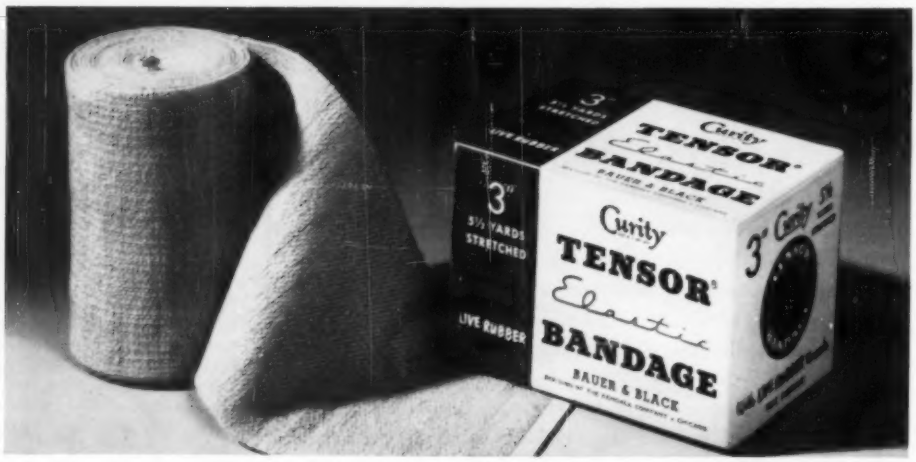

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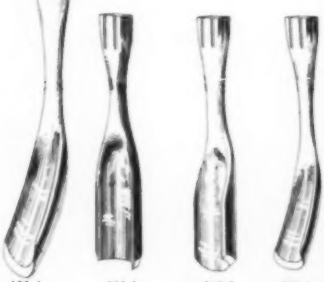

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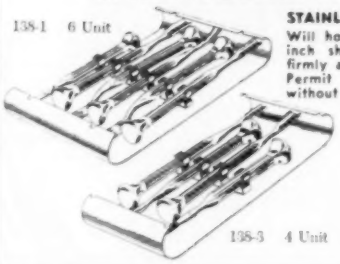

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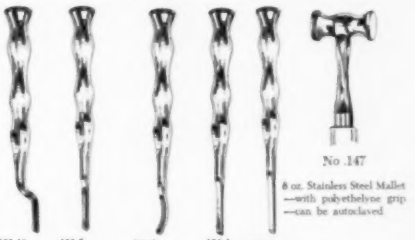

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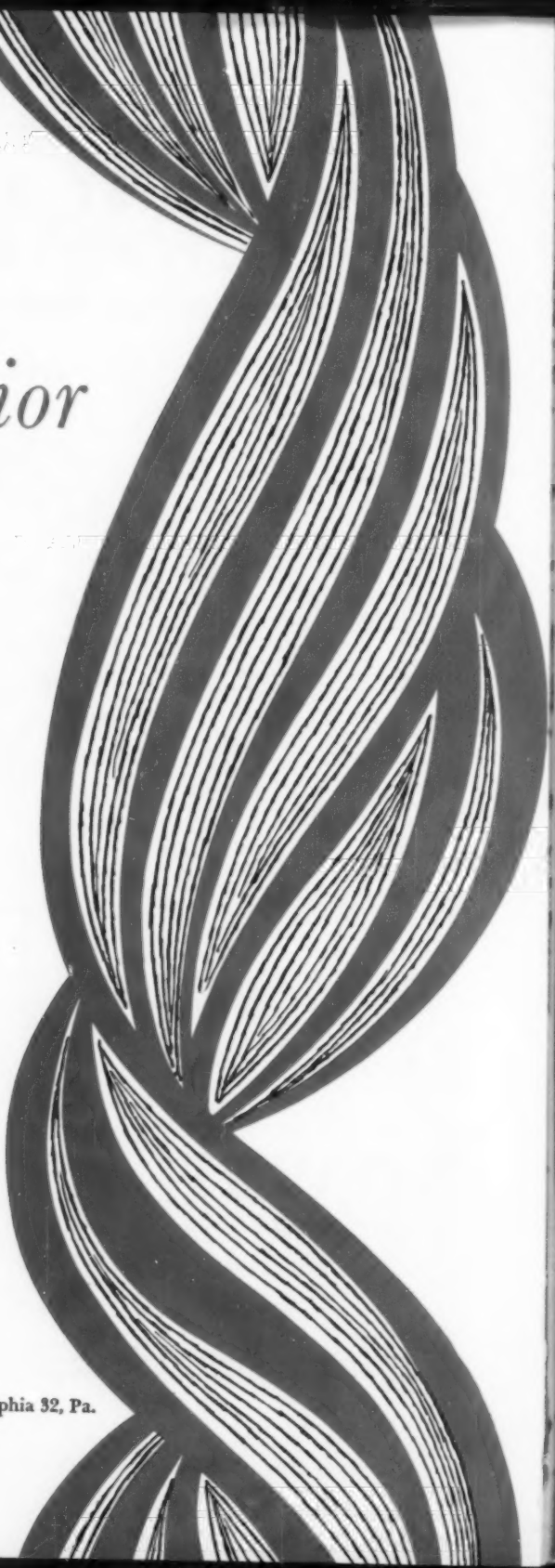

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REFERENCES—(1) Settel, E.: Personal communication. (2) Holley, H. L.: Personal communication. (3) Burns, J. J.; Trousof, N., and Brodie, B. B.: To be published. (4) Smith, R. T.: To be published. (5) Peak, W. P., and Smith, R. T.: To be published. (6) Wiesel, L. L.: Personal communication. (7) Passarelli, W. W.: Personal communication.

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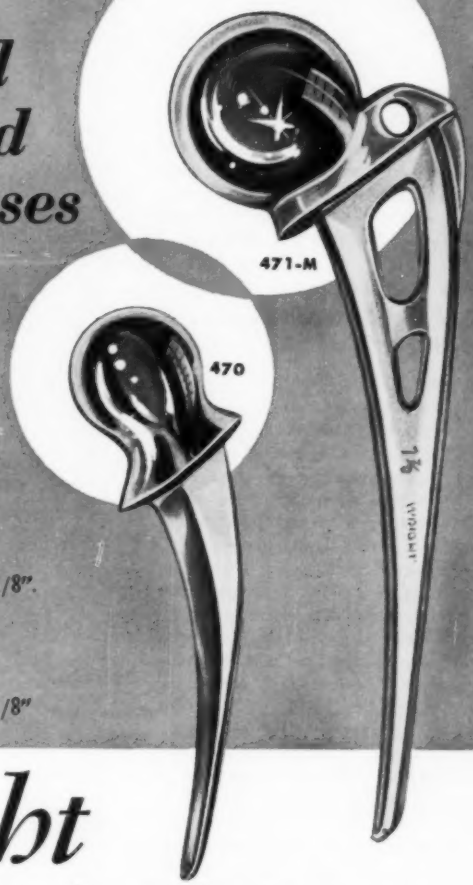

Wright

Manufacturing Company

Each prosthesis manufactured by Wright is precision constructed of the finest materials to rigid specifications and must pass the most exacting Zyglo inspection before being released for use. These prostheses closely approximate the anatomical configurations of the femur.

STAINLESS STEEL RASP ASSURES MAXIMUM ACCURACY IN SHAPING HARD INNER CORTICAL BONE OF MEDULLARY CAVITY OF THE FEMUR.

WRIGHT MFG. CO. • 880-882 ADAMS • MEMPHIS, TENNESSEE • TELEPHONE JAckson 5-0619

a four-flanged self-cutting MEDULLARY NAIL for internal fixation of the forearm

The Forearm

Intramedullary type internal fixation is desirable in the forearm to allow contact-compression at the fracture site and to minimize any interference with rotary motion of the radius about the ulna which occurs with metal plates.

Surgical Technique for Fractures of the Radius

In the case of both bone fractures of the forearm, the radius is usually internally fixed first. The fracture site is exposed through a dorsal-radial incision on the radial side of the extensor tendons. The medullary nail cannot be started retrograde as in the femur and ulna; it must be driven from the distal end of the radius proximally across the fracture site. This is somewhat difficult to do, and the details of technique should be closely followed. Another short longitudinal incision is made in the "snuff box" over the radial styloid. The thumb extensor tendons are retracted and the periosteum is incised over the radial styloid. A 7/64th inch drill hole is made from the tip of the radial styloid proximally into the medullary canal. This tract should be very carefully made because if a false oblique passage is made across through the other cortex, it is very difficult to change the direction. The 3 m m nail is bent to a mild curve on one end and introduced into the hole at the tip of the styloid process. The wrist is ulnar deviated, and the nail is driven proximally into the distal fragment medullary canal to the fracture site. The fracture is reduced and the nail driven proximally over the fracture site into the medullary canal of the proximal fragment.

by

Howard W. Schneider, M.D.

Harvey, Illinois

Surgical Technique for Fractures of the Ulna

A short, longitudinal incision is made over the subcutaneous surface of the ulna, and the fracture site exposed. The proximal fragment is lifted out into the wound with a bone hook or clamp. A long 7/64th inch drill is passed proximally into the medullary canal. A snug nail is then driven proximally up the medullary canal out through the olecranon, and a small skin incision made as the nail comes through. The nail is driven proximally until it passes the fracture site, and then the fracture is reduced. The fragments are held reduced with a bone clamp, and the nail is driven distally, and the fragments impacted. The most common sized nails are 4 to 5 m m and 18 to 26 c m long.

Schneider Self-Cutting Medullary Nails Advantages

- ★ Flanges prevent rotation of fragments.
- ★ Maximum strength for weight of nail.
- ★ Cuts its own way . . . less chance of splitting the shaft. (Nail does not get stuck.)
- ★ Larger sized nail can be used for a snug fit. (No problem of the narrow isthmus.)
- ★ May be driven or extracted from either end
- ★ No chance of getting out of the groove. (As with separate broaches and nails.)
- ★ Grooves allow for free outflow of marrow fat.

SIZES: 3, 4, 5 & 6 mm diameters . . . ulna and radius.

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BADGLEY CONTACT BLADE PLATE

for Fractures of the Hip

INTRACAPSULAR
EXTRACAPSULAR
INTERTROCHANTERIC
and SUBTROCHANTERIC

THREE PRIMARY FUNDAMENTAL PRINCIPLES:

1. TRIFLANGED BLADE FIXATION. STANDARD 6" LENGTH ASSURES ACCURATE NAIL LENGTH AS EXCESS LENGTH IS PRUNED.

2. CORTICAL FIXATION BY LATERAL PLATE ASSURES STABILITY OF THE BLADE.

3. FREE SLIDING OF BLADE IN CONTACT PLATE PRODUCES CONTINUOUS CONTACT AT FRACTURE SITE BY EXTRUSION OF THE BLADE OUTWARD. THE TRIFLANGED FEMALE COMPONENT OF THE CONTACT PLATE FOR THE BLADE PREVENTS ROTATION.

TECHNIQUE

INSERTION FOLLOWS TECHNIQUE OF THE SMITH-PETERSON NAIL. GUIDE WIRE MAY BE EMPLOYED IF DESIRED.

ESSENTIAL —— APPLY PLATE AND BLADE ASSEMBLED TO THE FEMUR TO MARK THE THREE FLANGES ON THE CORTEX OF THE FEMUR FOR PROPER INTRODUCTION OF BLADE SO PLATE WILL LIE IN PROPER RELATIONSHIP TO FEMORAL SHAFT. THE CORTICAL MARKINGS OF THE BLADE ARE THEN DEEPENED BY SMALL DRILL AND OSTEOTOME, OR DRILL 1/2" OPENING THROUGH OUTER CORTEX. THE NAIL MUST BE INSERTED SO THAT THE PLATE WILL LIE IN PROPER RELATIONSHIP TO THE SHAFT OF THE FEMUR. DISPLACE PLATE THEN UP THE BLADE, OUT OF THE WAY, BUT DO NOT REMOVE IT. DRIVE BLADE INTO HEAD AIDED BY ROENTGENOGRAMS. THE SIX INCH BLADE IS LONG ENOUGH TO ALWAYS ALLOW PERFECT LENGTH FOR NAIL FIXATION. THE UNNECESSARY LENGTH OF THE BLADE IS CUT OFF BY THE SPECIAL CUTTER.

THE PLATE IS SECURED TO THE SHAFT AFTER ACCURATE NAILING IS SUBSTANTIATED BY ROENTGENOGRAMS AND THE OVER-LENGTH OF THE BLADE HAS BEEN CUT OFF. THE COLLAR ATTACHMENT TO THE CUT END OF THE BLADE IS APPLIED. THIS SERVES A DUAL PURPOSE: (A) PREVENTION OF SOFT TISSUE IRRITATION. (B) PREVENTION OF INWARD DISPLACEMENT OF THE BLADE.

Carl E. Badgley
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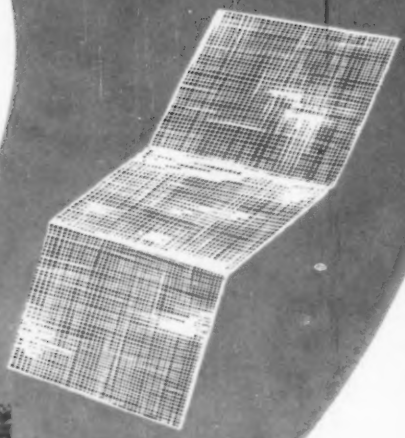

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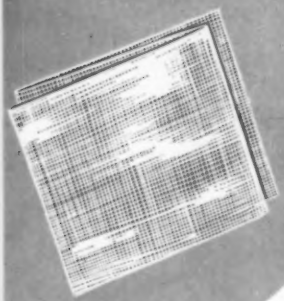

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1/2″x 72″	3″x 18″
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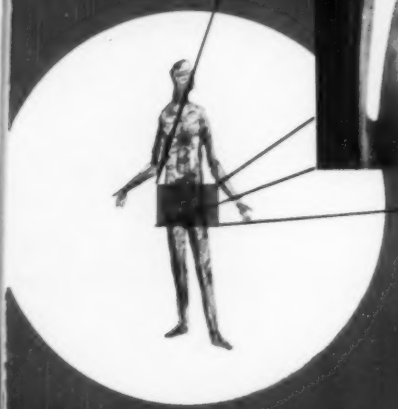
VITALLIUM® HIP PROSTHESES . . .

A PROGRESS REPORT

Roentgenogram of a bilateral arthroplasty utilizing Vitallium Moore prostheses.



"Most of the results are satisfactory, some are excellent. I am confident that they have been more successful than could be expected from any other reconstructive or arthroplastic procedure. With careful control, the prosthesis may give satisfactory service throughout the patient's lifetime." [1]

In 22 years of use, over 7,000,000 Vitallium appliances have been surgically implanted and there has never been one authenticated case of corrosion reported.

INDICATED USES FOR HIP PROSTHESES ACCORDING TO PROFESSIONAL REPORTS

- Acute Unstable Fractures (Pauwels' Cl. III) [1, 2, 4, 5]
- Acute Fractures in the Aged [2, 3, 4, 7, 8]
- Ununited Fractures (Long-Term) [1, 3, 4, 9]
- Delayed Non-Union [2, 8]
- Pathological Fractures [1, 2, 4, 6, 7]
- Aseptic Necrosis [1, 2, 4, 7, 9]
- Avascular Necrosis [3]
- Osteoarthritis [1, 2, 3, 6, 8, 10]
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IN THOUSANDS OF CASES VITALLIUM HIP PROSTHESES PROVED SUCCESSFUL

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REFERENCES:

*1. Moore, A. T.: The Self-Locking Metal Hip Prosthesis. J. Bone & Joint Surg., 39A:811,1957. 2. Symposium on Femoral Head Replacement Prostheses. J. Bone & Joint Surg., 36A:607,1954. 3. Severeano, A.A., Segal, L.A., and Zacchino, V.: Treatment of Fractures of the Neck of the Femur with Intramedullary Stem Prosthesis. J. Bone & Joint Surg., 40A:731,1958. 4. Mahoney, T.W., Hallenbeck, J.H., Jahr, J. and Dowling, J.A.: Immediate Moore Prosthetic Replacement in Acute Intracapsular Fractures. Am.J.Surg., 95:577,1958. 5. Smithfield, R.E., Cooperman, S. and Shaw, C.W.: Replacement of the Femoral Head by Judet or Austin Moore Prosthesis. J. Bone & Joint Surg., 39A:1063,1957. 6. Lippman, R.K.: The Transfixion Hip Prosthesis. J. Bone & Joint Surg., 39A:759,1957. 7. Obermiller, R.E.: The Present Status of Surgery of the Hip. Rocky Mountain M.J.,54: 237,1957. *8. Raven, C.E., and Detweiler, R.C.: Fractures in the Aged. J.A.M.A., 165: 1317, Dec. 22, 1956. *9. Thompson, F.R.: Two and a Half Year's Experience with a Vitallium Intramedullary Hip Prosthesis. J. Bone & Joint Surg., 36A: 489,1954. *10. Moore, A.T.: Metal Hip Joint; A New Self-Locking Vitallium Prosthesis. South. M.J., 43: 1015,1950.

*REPRINTS OF THESE PAPERS AVAILABLE ON REQUEST.

Moore's observation is one of many recent statements concerning treatment of the so-called "unsolvable fracture." Once considered the plague of the elderly, fractures of the hip can now be treated with less risk and shock than was believed possible just a few years ago.

"The indications for the use of prostheses appear to be becoming more clearly defined. Non-union, arthritis, and asceptic necrosis are almost universally accepted as indications, while the use of prostheses in fresh fractures of the femoral neck at any age, but in the aged particularly, is increasing." [2] "Use of the femoral-head prosthesis in fresh fractures, when indicated, may reduce the incidence of uraemia, hypostatic pneumonia and death." [3]

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Every Vitallium hip prosthesis is made with exacting care and precision. From selection of the virgin metals to the finished product, Austenal's quality control procedures assure you of the very best prosthesis worthy of permanent implantation.

"Vitallium was selected as the metal of choice because of its long-proved ability to remain absolutely unchanged within the body. The assurance is lacking in steel, in acrylics, and in nylon." [9] "Apparently Vitallium is inert in the tissues, and it is possible that the prosthesis may last indefinitely." [1]

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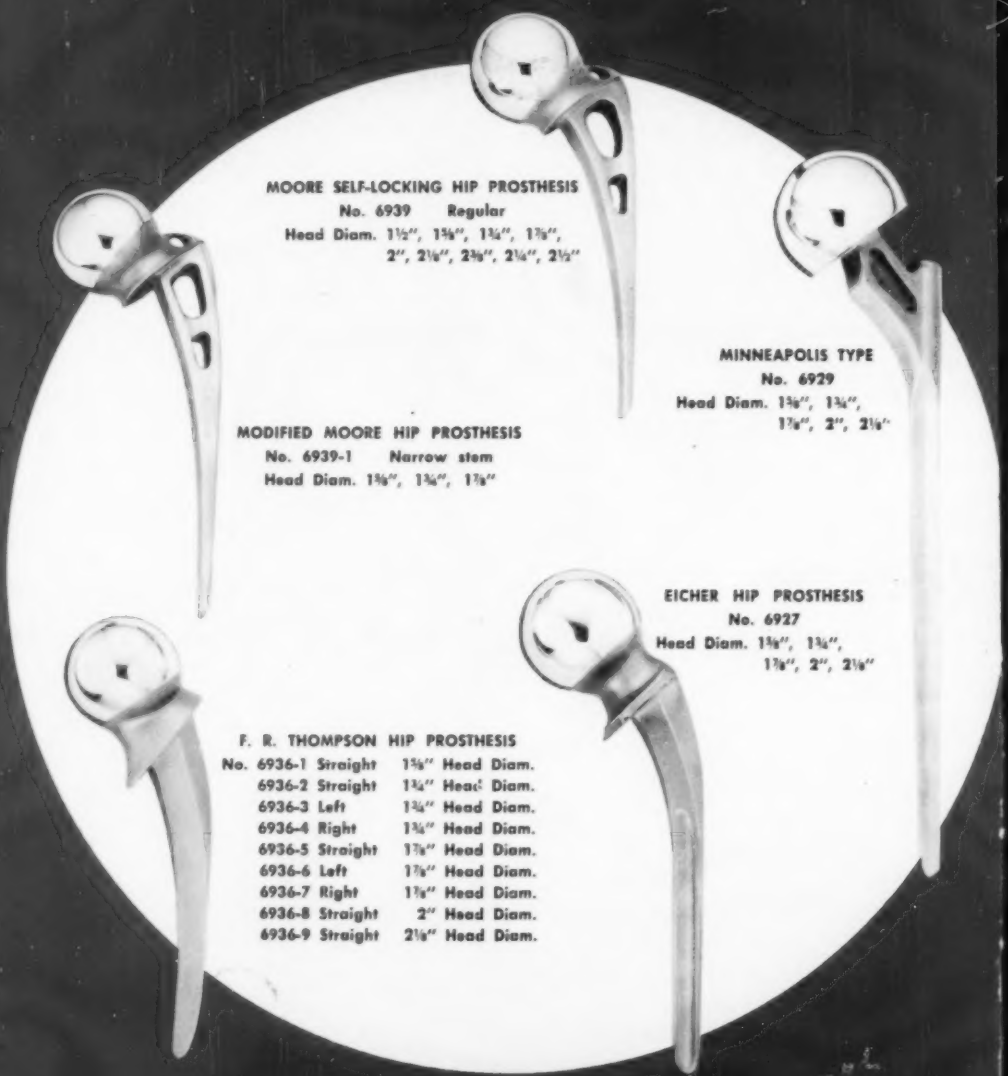

MOORE SELF-LOCKING HIP PROSTHESIS
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Head Diam. 1½", 1⅝", 1¾", 1⅞", 2", 2⅛", 2⅜", 2¼", 2½"

MINNEAPOLIS TYPE
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Head Diam. 1⅝", 1¾", 1⅞", 2", 2⅛"

MODIFIED MOORE HIP PROSTHESIS
No. 6939-1 Narrow stem
Head Diam. 1⅝", 1¾", 1⅞"

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No. 6927
Head Diam. 1⅝", 1¾", 1⅞", 2", 2⅛"

F. R. THOMPSON HIP PROSTHESIS

No. 6936-1	Straight	1⅝" Head Diam.
6936-2	Straight	1¾" Head Diam.
6936-3	Left	1¾" Head Diam.
6936-4	Right	1¾" Head Diam.
6936-5	Straight	1⅞" Head Diam.
6936-6	Left	1⅞" Head Diam.
6936-7	Right	1⅞" Head Diam.
6936-8	Straight	2" Head Diam.
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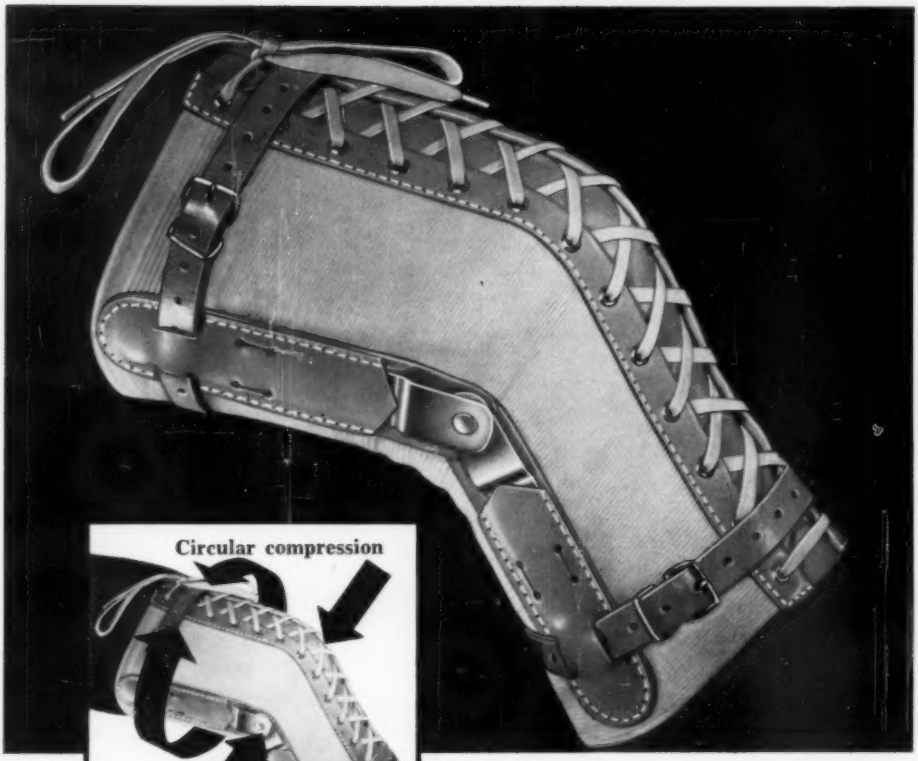

Truform Hinged Kneecaps Model 968 laced front (pictured), Model 969 without lacing, Model 970 without lacing or two encircling straps.

CONTROLLED stability

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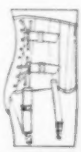
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Spencer's Individual Designing Service is available to you through Corsetieres specially trained to help you help your patients.

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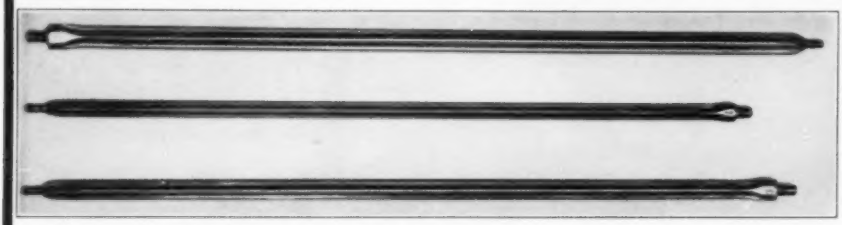

***LOTTES* FEMORAL NAILS** are manufactured with diameters of 3/8, 7/16, and 1/2 inches —with lengths in 1/2 inch variations from 14 to 20 inches.

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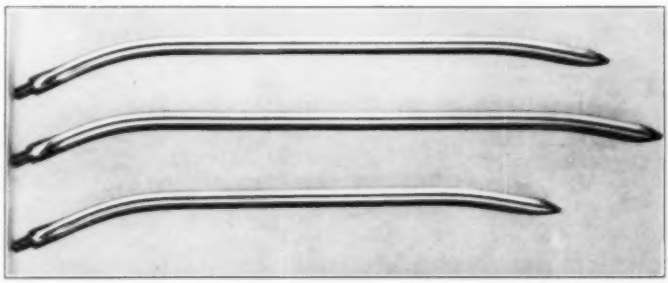

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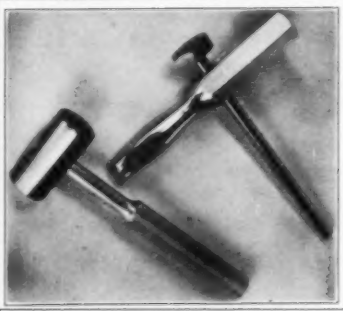

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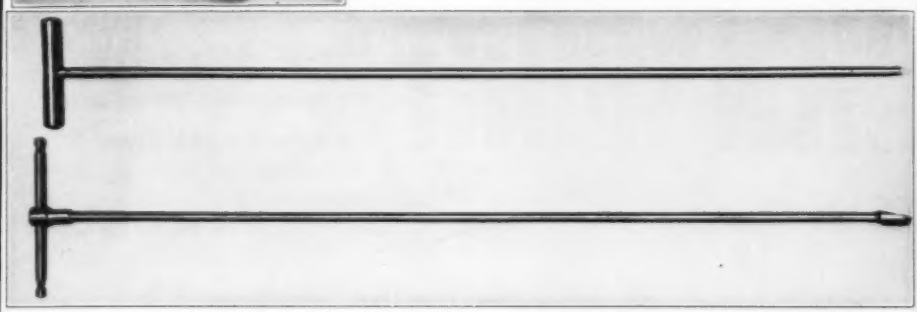

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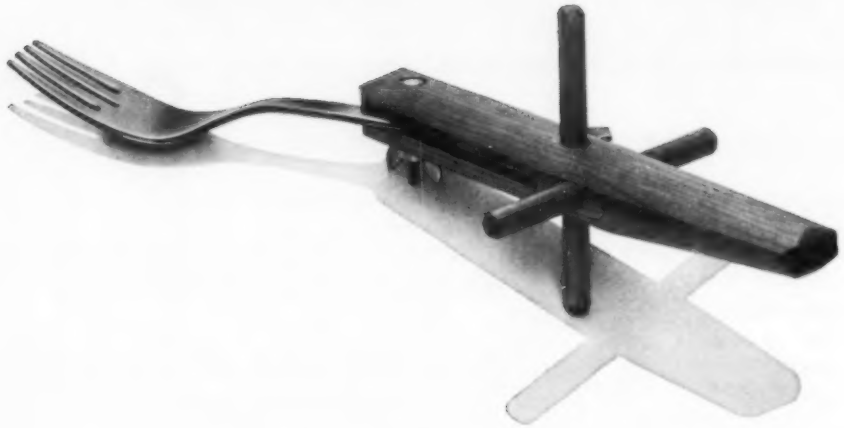

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- with far less gastric disturbance
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Swing tongue aside and *See* perfect fit!

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Now a shoe with a smooth, seamless back!

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* Including congenital talipes equino-varus, congenital calcaneovalgus, cerebral palsy (spastic paralysis), congenital subluxation or dislocation of the hips, bow legs and knock knees.

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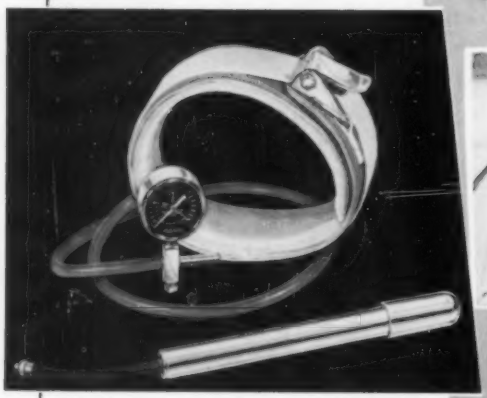

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Removal of the tourniquet can be effected in 2 seconds...

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OSTIC® PLASTER BANDAGES
won't give you casts this strong

But they give you the strength any patient needs— and all these extras, too:

	OSTIC	Bandage B	Bandage C
Waterproof package (prevents presetting)	YES	NO	YES
Setting time controlled within 20 seconds	YES	NO	NO
Available in both fast and extra-fast setting	YES	YES	NO
Plaster loss less than 3%	YES	YES	YES
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Available in colors for kids	YES	YES	NO
Colors are washable pigments (not dyes). Won't stain fabrics. No gloves needed.	YES	NO	—

GIVE KIDS MEMBERSHIPS IN THE CURITY HERO CLUB

Youngsters' spirits rise when you make 'em members of the Curity Hero Club. (And you get better co-operation.) Hero's badges and certificates of membership packed inside every box of Ostic in Colors.

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A double amputee, Harvey A. Macy, says: "The pair of Hip Control AK Hanger Limbs are as near perfect as I believe an artificial leg can be. I am satisfied with them in every detail—looks, comfort, and performance. I drive my car with only one added feature, a special hand throttle." Hanger Artificial Limbs here have made possible the important thing for every amputee—returning to self-reliant daily life. Careful fitting and manufacture have done the same for thousands of Hanger Wearers for 95 years.

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AVAILABLE AT AUTHORIZED FACILITIES IN THE FOLLOWING CITIES:

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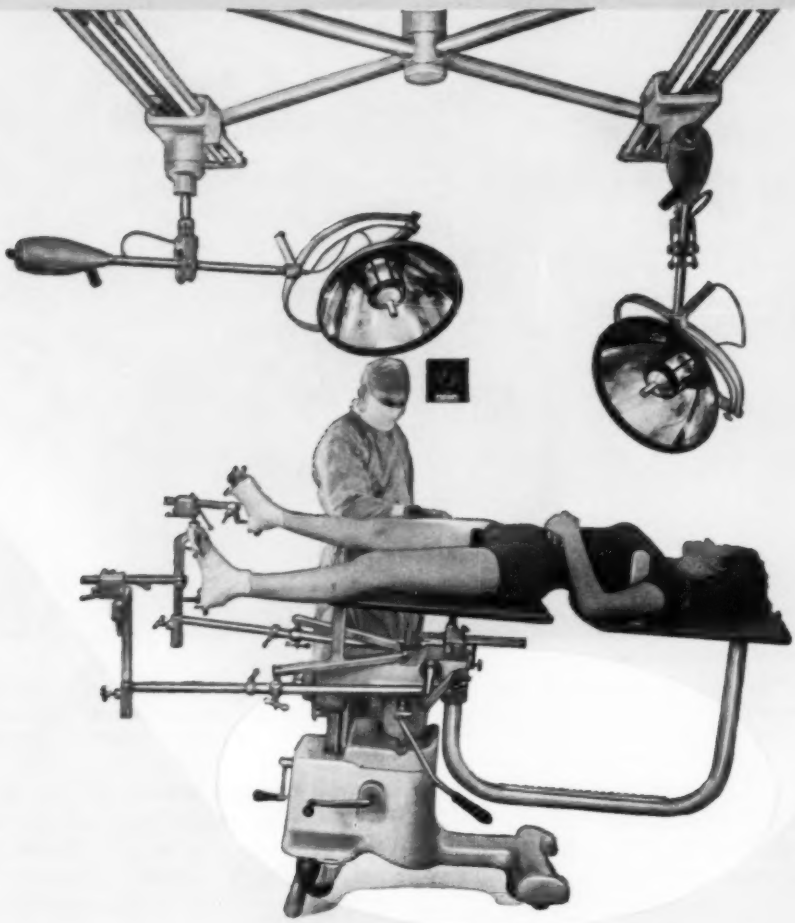
Precise Positioning and Positive Fixation—

with AMERICAN-Albee

ORTHOPAEDIC *and* FRACTURE TABLE



● Acknowledged as the most versatile in its field, the American-Albee Orthopaedic and Fracture Table enables the orthopaedic surgeon to achieve "perfect positioning" of short, tall, obese and even infant patients . . . easily and rapidly. It is designed to accommodate closed fracture reductions as well as the increasing demands of complex orthopaedic surgery. Thus, to orthopaedists the world over, the name American-Albee identifies the table of choice for this comprehensive branch of medicine.

Ideal complement to this improved table is the American DV-22 Major Surgical Light . . . a new concept in easily maneuverable illumination . . . cool, shadowless, color-corrected . . . intensity to 10,000 foot candles *from a dual source.*

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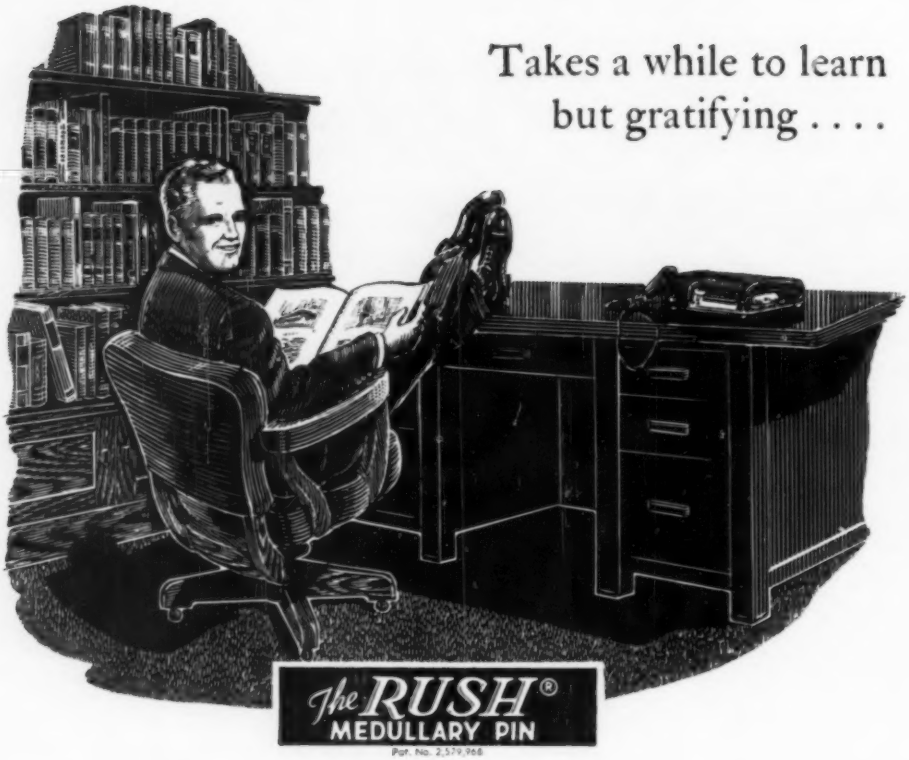
Takes a while to learn but gratifying . . . .



Proper application of the RUSH PIN is not always easy. It takes a while to learn. It is quite different in principle and technic from other forms of medullary fixation. It is not designed to impact the marrow cavity, but to accurately transfix the fractured bone by points of pressure, precisely applied.

The ingenious surgeon, who has added this to his knowledge and skills, has simplified his tasks and contributed pleasure to his patients. He minimizes surgery and speeds convalescence with unbelievably early motion, even in fractures near joints. Removable splints are sometimes used, but casts or traction, rarely.

The patient is more comfortable, the hospital stay is shortened. And best of all, the recovery time and residual disability can be markedly lessened.

It does take a while to learn, but it IS GRATIFYING!

Write for Information

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MERIDIAN, MISS.

EXCLUSIVE MANUFACTURERS OF **RUSH** MEDULLARY PINS AND INSTRUMENTS
Publishers of **"ATLAS OF RUSH PIN TECHNICS"** by LESLIE V. RUSH, M. D.

Lock the bone with dynamics

The RUSH® MEDULLARY PIN

Pat. No. 2,379,166

MINIMIZE TRAUMA
EXPEDITE RECOVERY
SIMPLIFY REMOVAL

Rush Pin Technics require some understanding of physical principles, but results reward the effort. It is the opposition of dynamic forces which provides the fixation.

An astounding variety of complicated fractures, even comminuted ones near joints, are amenable to this means once the basic factors are understood.

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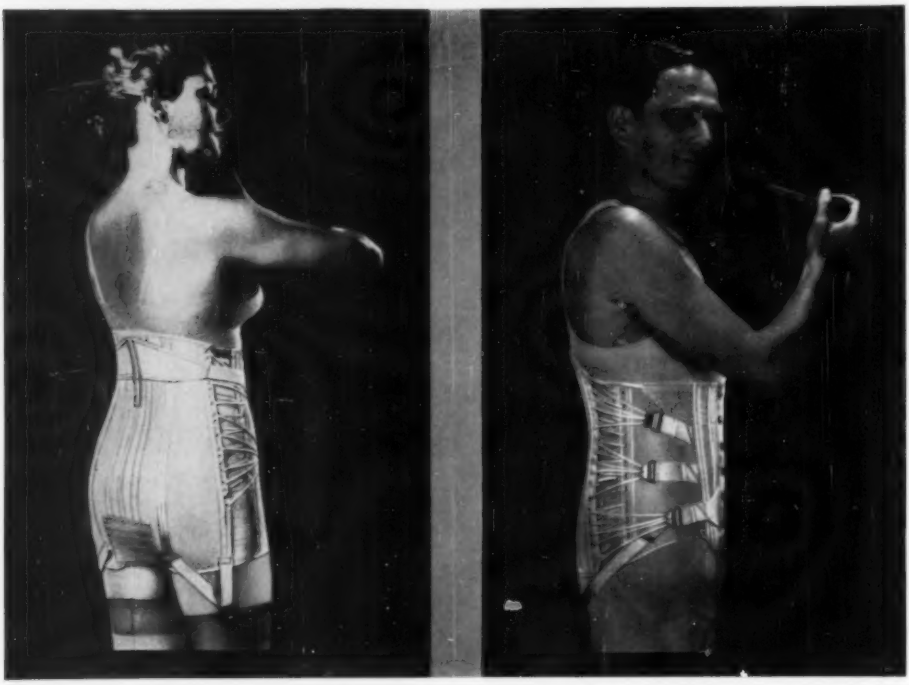
CAMP LUMBOSACRAL SUPPORTS



Camp fabric lumbosacral supports play an important part in the conservative treatmen of orthopedic conditions. They steady and limit the motions of the joints, ligaments and muscles in injuries and diseased conditions of the low back. Available without or with steel upright reinforcements or with the Camp spinal brace as needed.

Camp's Lumbosacral Supports are scientifically designed to give a secure fit to the pelvic girdle, the upper lumbar and the low dorsal spine, including the entire abdomen in front, thus giving maximum lumbar spine support with the greatest patient comfort.

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Relieves Spasm, Pain, and Depression too

Patients with muscle spasm of the usual types demand relief first. Disipal fills this need. In sprains, strains, fibrositis, noninflammatory arthritic states and other musculoskeletal disorders, Disipal not only relieves the spasm, but alleviates the depression which so often accompanies pain of any type.

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Highly selective action...energizing against weakness, fatigue, adynamia and akinesia...potent against sialorrhea, diaphoresis, oculogyria and blepharospasm...lessens rigidity and tremor...alleviates depression...safe ...even in glaucoma.

*Trademark of Brocades-Stheeman & Pharmacia. U. S. Patent No. 2,567,351. Other patents pending.

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FOR BACK SUFFERERS
who drive cars

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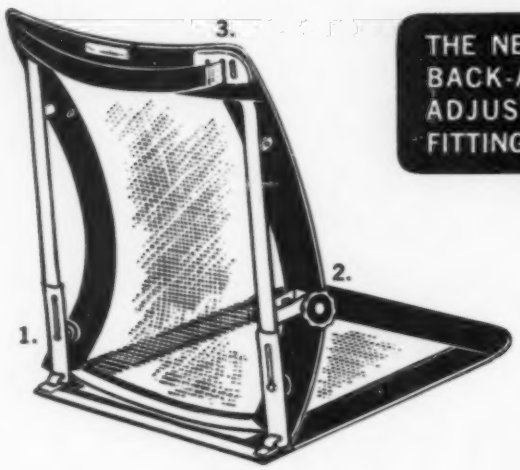

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Obesity, pregnancy, arthritis, sciatica, slipping and degeneration of discs, abdominal surgery, postural strain — for these, and similar complaints involving the musculo skeletal system, particularly of the lower back, the Mark-Fore adjustable Back-Aide was scientifically designed.

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SPECIAL OFFER TO DOCTORS: Send this coupon today for a Mark-Fore adjustable Back-Aide at the professional price of $7.50 postpaid (regular retail price: $12.95), and/or descriptive literature for distribution to patients. Each Mark-Fore adjustable Back-Aide is constructed of Fiberglas mesh with a special alloy steel frame and luxurious Lum-Puf Saran and heavy vinyl leatherette.

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Please send me a Mark-Fore adjustable Back-Aide at the professional price of $7.50 postpaid in the following color combination:

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KANTREX

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"STUBBORN SPECTRUM"

bactericidal

antibiotic

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under auspices of
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JULY 10 AND 11, 1958

Chemical, microbiological, pharmacologic and clinical aspects reviewed in 35 papers by eminent investigators. For a complimentary copy of the complete proceedings, write to

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–bactericidal

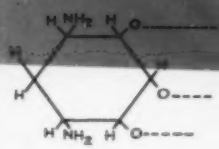
against a wide variety

of recalcitrant organisms

–even against

resistant staph!

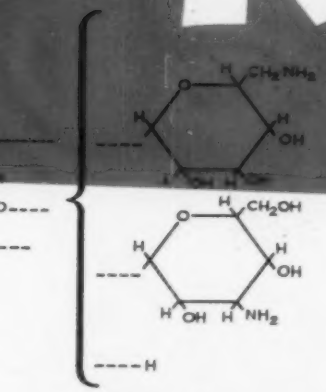
A new "stubborn spectr



Clinical studies show that many stubborn organisms resistant to chloramphenicol, penicillin, streptomycin, erythromycin, chlortetracycline, tetracycline, oxytetracycline, oleandomycin, and novobiocin—singly or in combination—are sensitive to KANTREX.

ctrum" antibiotic–

KAN



KANTREX—an antibiotic derived from *Streptomyces kanamyceticus*—is bactericidal against a wide variety of Gram-positive and Gram-negative organisms, including strains of *Micrococcus pyogenes* var. *aureus*—the most notorious of the "resistant staph."

TREX

Kanamycin Sulfate

–for intramuscular

TYPICAL CASE HISTORIES

"A THERAPEUTIC TRIUMPH"

*in staphylococcal endocarditis**

L.B., an adult male, was diagnosed as having tricuspid endocarditis w multiple pulmonary septic infarcts, due to a penicillin-resistant *Stap lococcus aureus hemolyticus*. He was acutely ill and, after receiving million units of penicillin a day, plus 2 Gm. of erythromycin, continu a "striking downhill course."

Intramuscular kanamycin (KANTREX) was started at a dosage of 0.5 G t.i.d. for 3 days, after which it was raised to 1.0 Gm. t.i.d. and continu for 5 weeks. Following this, the dosage was lowered to 0.5 Gm. t.i.d. 2 weeks. No evidence of any kind of kanamycin toxicity was obser during the 7½ weeks of therapy.

A prompt temperature drop occurred by the fourth day of KANTI therapy. Subsequently, X-rays showed resolution of the septic infar

The patient was discharged as recovered on 2/7/58, and a clinical follo up since then showed him to be entirely well. This case was described the investigator as "a therapeutic triumph."

*Sol Katz, District of Columbia General Hospital, Washington, D.C.: Personal communica

Among the pathogenic organisms susceptible to KANTREX are various strains of *Staph. aureus* and *albus, Proteus, A. aerogenes, Klebsiella pneumoniae, Salmonella, Shigella, E. coli, paracolobacterium, Pseudomonas* and *enterococcus.*

Preliminary studies indicate that KANTREX is a promising agent against *Mycobacterium tuberculosis,* including streptomycin- and isoniazid-resistant strains.

REX™

Kanamycin Sulfate

for resistant organisms—

KANTREX

Kanamycin

FROM "TERMINAL" STATE TO COMPLETE RECOVERY

*in septicemia and pneumonia**

A.B., a 1-year-old girl, had received chloramphenicol, erythromycin, penicillin, and bacitracin without effect, for septicemia and pneumonia due to *Staphylococcus aureus*.

KANTREX was started on the 18th day of her illness in a dosage of 15 mg./Kg. a day for the first day, and 10 mg./Kg. for 25 days, in divided doses. Total dosage for the 26 days was 1.68 Gm.

A "dramatic improvement" was noted immediately after KANTREX was started. Although the patient seemed "terminal" before KANTREX was administered, she showed rapid improvement, and X-ray evidence of the disease gradually disappeared. She was discharged "completely well." No toxic reactions were observed.

*E. M. Yow and O. Monzon, Dept. of Medicine, Baylor Univ. College of Medicine, Houston, Tex.: Personal communication.

Indications

Indications for KANTREX include infections due to kanamycin-susceptible organisms:

Respiratory infections: laryngitis, tracheitis, bronchitis, pneumonitis, broncho-pneumonia, lung abscess, pleuritis, empyema and bronchiectasis.

Urinary tract infections: acute and chronic pyelonephritis, cystitis.

Soft tissue infections: wound infections, abscesses, cellulitis, osteomyelitis, blood stream infections.

Dosage

Adults: Average daily intramuscular dose 1 to 2 Gm. in 2 to 4 equally divided doses.

Children: Average daily intramuscular dose 15 to 30 mg. per Kg. in 2 to 4 equally divided doses.

Precaution

In the course of extensive clinical trials, signs of renal irritation and skin eruptions (which disappeared on cessation of therapy) were occas
noted. Signs of eighth nerve dysfunction—
tus, vertigo and loss of hearing—were obse
a few patients. These patients were pr
nantly over forty-five years of age; all
ceived 18 grams or more of KANTREX.
latter respect it would appear that KANTR
less toxic potential than streptomycin.

Supply

KANTREX is available in rubber-capped v
a ready-to-use sterile aqueous solution
concentrations (stable at room tempe
indefinitely):

KANTREX (kanamycin sulfate) 0.5 G
in 2 ml. volume.

KANTREX (kanamycin sulfate) 1.0 G
in 3 ml. volume.

Also available: KANTREX (kanamycin s
Capsules, 0.5 Gm. for preoperative bowe
sepsis; bottles of 20 and 100.

Comprehensive literature available on request

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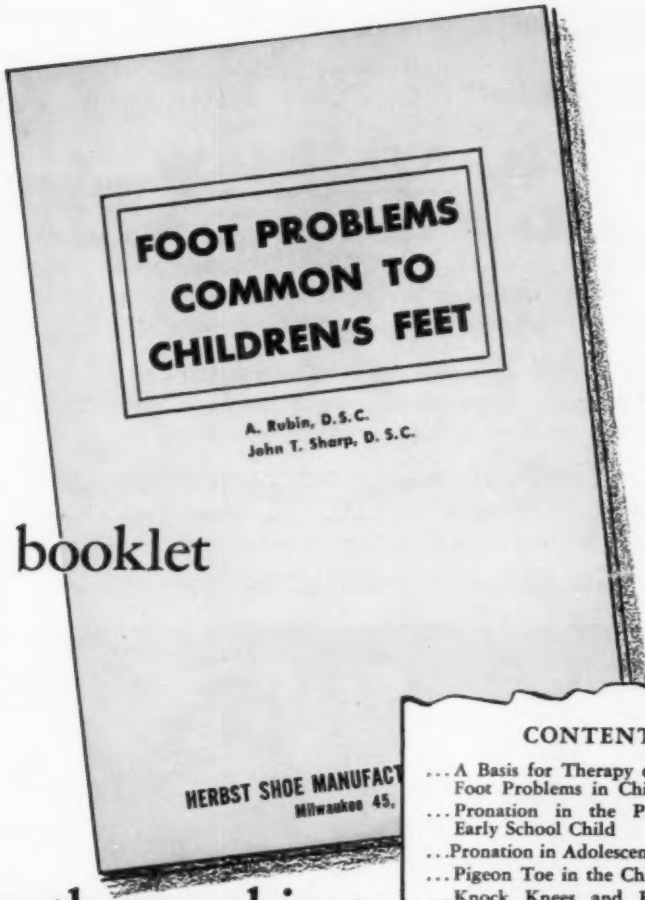

This booklet covers these subjects

CONTENTS

...A Basis for Therapy of Mechanical Foot Problems in Children
...Pronation in the Preschool and Early School Child
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...Pigeon Toe in the Child
...Knock Knees and Bow Legs in the Child
...Painful Heels
...Toe Walkers

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Professionally written and illustrated with diagrams for corrective wedging, this booklet is helpful in providing "refresher" reading on a group of topics that physicians are being asked about with increasing frequency.

It is being offered purely as a service to the profession by the makers of CHILD LIFE Shoes.

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DEMAND GENUINE **NEUFELD NAILS** *and* **SCREWS**

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NEUTRILIUM® is the most non-corrosive metal known to science. Its proven super-strength lends an assurance of permanence to internal fixation of the trochanteric area. This neutral, non-magnetic, homogenetic alloy is entirely inert and therefore compatible with human bone or tissue, remaining unaffected by body chemistry.

NEUFELD BONE SCREWS — of ***NEUTRILIUM®*** — are cold forged and, unlike other metals, appear to be unbreakable under maximum human pressures. Heads will not twist off during application or in actual use.

GENUINE NEUFELD NAILS and SCREWS — of ***NEUTRILIUM®*** — made only by MEDICAL RESEARCH SPECIALTIES, Loma Linda, California, are sold nationally by leading surgical and orthopaedic supply dealers.

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NEUFELD FEMORAL NAIL PLATE
Used for internal fixation of intertrochanteric and subtrochanteric fractures.
Write for descriptive literature.
MEDICAL RESEARCH SPECIALTIES
Loma Linda, California

My back . . . it always hurts right here, Doctor.

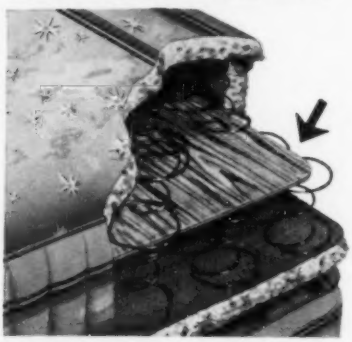
Doctor . . . I always get up with this miserable backache.

The bedboard helped a little . . . but my back still hurts a lot!

Familiar remarks, Doctor? Chances are you've heard them many times from patients with "problem backs."

IF YOU'VE wanted a sleeping surface to help alleviate backache caused by lack of proper mattress support, Simmons now offers a new concept in the orthopedic-type mattress.

Its name: BACK CARE—Its important feature: A BUILT-IN BEDBOARD



Note that the bedboard is centered in the mattress. The bedboard exerts corrective action close to the back where support is needed.

The bedboard rests between two layers of inner springs. The upper layer adjusts to body contours for sleeping comfort. The lower layer equalizes weight and prevents "sag."

Developed in consultation with orthopedists Many physicians reported that so-called "posture" mattresses and bedboards placed under ordinary mattresses are sometimes ineffective for patients with chronic backache.

In cooperation with a group of leading orthopedic surgeons, Simmons designed Back Care. It was tested by the Simmons Orthopedic Panel to determine its usefulness as an aid to therapy for chronic back disorders.

In the opinion of these specialists, Back Care with Built-in Bedboard is an important adjunct to management of backache since it combines desired degree of firmness . . . and comfort.

Demonstration of the unique features of Back Care will, we believe, convince you that it can afford relief to many of your patients.

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WITH BUILT-IN BEDBOARD

by SIMMONS

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Handpieces for the Stryker Electro-Surgical Unit . . .

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Here is Orthopedic Frame's answer to the demand for the finest grafting instrument possible.

Graft thickness is accurately obtained by a single calibration lever on the right side of the instrument. Minimum setting, 5/1000"; maximum setting, 30/1000". Adjustable graft widths, 3", 2¼", 1½ inches.

Two rollers in front and one behind the oscillating blade eliminate tension as the skin comes in contact with the disposable blade. Few moving parts . . . two year guarantee.

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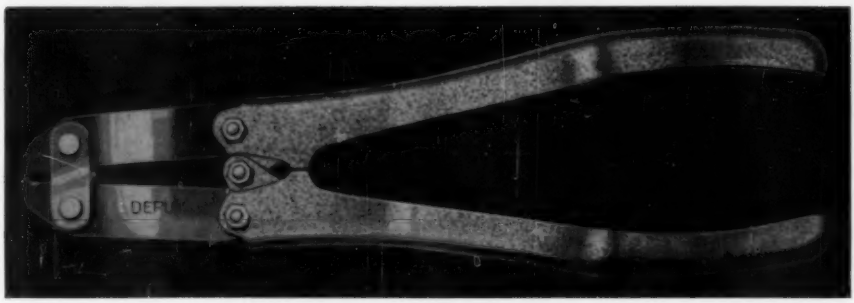
The First Completely Adjustable Intertrochanteric Bone Plate!

The new DePuy Universal Bone Plate is designed to provide both vertical and lateral angulation. In use with conventional Smith-Petersen Nails, cannulated or non-cannulated, or with Lorenzo Screws, it can be regulated quickly and easily during surgery to suit a wide variety of anatomical conditions. Bending of the plate is not required. A range of 35° in the vertical plane of the plate and nail or screw compensates for variance of angle between the femoral head and shaft of the femur. Also, there is a 15° range of lateral adjustment which permits the plate to be moved into flush position after the nail or screw has been impacted. Once angulation is properly adjusted rigid fixation is assured by exclusive concave, serrated locking washer, which is held in place with either the double locking screw combination or a solid Hex bolt. Finest SMO stainless steel. **No. 693.**

DePuy PIN CUTTER



The new DePuy Pin Cutter is designed to meet the need for a powerful end cutter that can cut the pin off flush. This sturdy instrument easily cuts pins up to 3/16" diameter. The jaws are made of especially hardened tool steel to insure long life. The handles, made of plated steel, connect to the jaws through a powerful cam that permits easy operation even when cutting larger size pins. **No. 686.**

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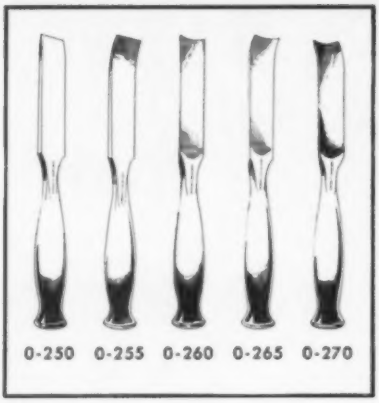

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0-270 SMITH-PETERSEN GOUGE—reverse curved, 8", sizes ⅜", 9/16", ¾" and 1". Stainless Steel.

A NEW STAINLESS STEEL CASE TO HOLD SMITH-PETERSEN OSTEOTOMES and GOUGES

0-295 Open

CASE 0-295—holds seven Smith-Petersen Osteotomes.

CASE 0-296—holds seven Smith-Petersen Gouges.

CASE 0-297—holds a combination of seven Osteotomes and Gouges.

Cutting edges are protected at all times. Complete unit may be autoclaved.

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Specify Width of Gouges and Osteotomes When Ordering

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PEPTIC ULCER	less than 1½%
OSTEOPOROSIS	only ⅙ of 1%
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never reported with METICORTEN– noted with the more recent steroids: unexplained leg cramps, lightheadedness, headaches, tiredness, weakness, anorexia

1, 2.5 and 5 mg. white tablets

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nothing takes the place of experience especially in long-term steroid therapy

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Specialist
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EXTRA FAST
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VOL. 40-A, NO. 4 JULY 1958

The Journal of
Bone and Joint Surgery

American Volume

The Surgical Management of Chronic Tophaceous Gout

BY WILLIAM A. LARMON, M.D., CHICAGO, AND JAMES F. KURTZ, M.D., HINES, ILLINOIS

From the Department of Orthopaedic Surgery, Northwestern University Medical School, Chicago, and the Orthopaedic and Rheumatology Services of the Veterans Administration Hospital, Hines

Gout is a disease of abnormal metabolism of uric acid and its precursors, characterized by an increase in the concentration of uric acid in the blood. The disease is one of antiquity. Medical writings dealing with the subject date from the time of Hippocrates. In recent years, the literature concerning the medical management of gout, the altered metabolic phenomenon, and the chemistry of the disease has been voluminous. Numerous rewarding experimental studies have added immeasurably to our knowledge of the nature of gout and the medical management of the problem.

In reviewing recent and ancient medical writings, one is impressed with the lack of studies of the surgical management of chronic tophaceous gout. Until Linton and Talbott described surgical techniques for removing tophi in 1943, little had appeared in the literature on this subject. No comprehensive articles dealing with the surgical management of chronic tophaceous gout have appeared since then. It is this apparent lack of interest in the surgical management of chronic tophaceous gout, as evidenced by the paucity of literature on the subject, that prompted this study. It seems that the chronic form of gout logically falls within the province of the orthopaedic surgeon since this disease is a destroyer of the musculoskeletal system.

This report is based on the surgical management of twenty-three patients with chronic tophaceous gout admitted to the Veterans Administration Hospital, Hines, Illinois, from 1947 to 1957. In the twenty-three patients, ninety-nine surgical procedures had been performed. From a study of these, an attempt is made to correlate the medical and surgical management of this disease.

Gout is often described as a rare affliction, and until recent times it was attributed to dietary indiscretion. Work by many investigators in the past decade showed that the increased level of uric acid in the blood is due to a metabolic defect in the formation of uric acid.

Uric acid is a normal end product of purine metabolism. Its source may be exogenous from our food or endogenous from cellular metabolism. A third source of uric acid may be by direct synthesis from simpler nitrogen, carbon, hydrogen, and oxygen compounds. This concept is based upon studies with various radioactive isotopes and indicates that the gouty patient forms an abnormal amount of uric acid from these various sources.

Tophi do not form in all patients suffering from gout. Of the cases studied by Linton

and Talbott, 10 per cent of the patients had surgery because of tophus formation. This would agree with our series of twenty-three patients with tophaceous gout in a total number of 280 patients admitted to the hospital with a confirmed diagnosis of gout.

Tophaceous gout is a late manifestation of the more severe form of this metabolic disturbance. The majority of patients suffering from gout have recurring attacks of acute arthritis at irregular periods with no demonstrable permanent joint changes between attacks. It is probably because of lack of appreciation of the fact that tophi form late, that the disease is not diagnosed more often in the early stages. Certainly, if routine studies were carried out in patients with acute arthritis to determine the presence of elevated serum uric acid levels, many more cases would come to light in a stage amenable to medical management.

Talbott and others have called the total amount of freely diffusible uric acid in the body the metabolic pool. In the normal patient, this total pool varies between 700 and 1400 milligrams, the average being about 1000 milligrams. The rate of formation and excretion has been termed the rate of turn-over. In the normal individual, this turn-over rate varies from 0.5 to 0.9 metabolic pool per day. In patients with gout, the metabolic pool ranges from 2000 to 5000 milligrams with a decreased turn-over rate of from 0.35 to 0.50 pool per day.

Uricosuric agents, such as salicylates and probenecid, block renal tubular absorption of uric acid, thus increasing the excretion of uric acid. This tends to reduce the total metabolic pool.

It has been shown by Gutman and Yü and others that tophi may slowly regress when the patient is placed on a constant regimen of uricosuric agents, such as probenecid, when kidney function is adequate. However, in the patient with damaged kidneys (from gouty deposits or for other reasons) this effect of the uricosuric agents is lessened.

It is hoped that proper surgical management will lessen the destruction of the bones, joints, tendons, and soft tissues when combined with proper medical care.

INDICATIONS FOR SURGERY

Linton and Talbott removed tophi of the hands, feet, wrists, forearms, and elbows only and listed their indications for removal of tophi as follows:

1. Large tophi which have become unsightly as well as smaller tophi which interfere with the wearing of gloves or shoes;

2. Pain in tophi because of location over exposed areas, such as the olecranon, knuckles, ends of fingers, toes, and heels;

3. Interference with the movements of tendons or adjacent joints by tophi that involve the extensor or flexor tendons of the hand;

4. Any discharging sinus associated with tophaceous deposits;

5. Extensive deposits involving the fingers or toes.

Through the studies conducted on twenty-three patients, we have added to these indications for surgical treatment:

1. To lessen the total amount of urates in the body by removing large and readily accessible tophi;

2. To prevent further destruction of bone, joints, and soft tissues by enlarging tophi;

3. To minimize the danger of breakdown and necrosis of skin with the formation of ulcers when distension by tophi occurs;

4. To correct deformity of fingers and toes by resection of tophi and placing the parts in functional positions, when deformity of the bones and joints has occurred;

5. To stabilize painful joints particularly the weight-bearing joints, such as the ankle and subtalar joints, when they are destroyed or are painful from secondary hypertrophic arthritic changes;

6. To improve function and lessen pain by means of arthroplasty when this is

feasible in such locations as the radial head, distal portion of the ulna, hip joint, and the metatarsophalangeal joints;

7. To decompress nerves which have become secondarily involved by pressure from tophi adjacent to the nerve.

SURGICAL PATHOLOGY

Tophi tend to form primarily in the extremities distally (Fig. 1). In all of our patients, there was some involvement in the fingers and toes with lesser involvement of the wrists, elbows and shoulders, and feet, knees, and hips. Only one patient had proved involvement of the sacro-iliac joint, and none had proved involvement of the spine, although there have been several lesions suspect. There seems to be a predilection for the extensor surfaces of the extremities, although the flexor surfaces may be the site of tophus formation, particularly in the fingers and toes.

FIG. 1

FIG. 2

Fig. 1: Tophi present on the extensor surface of the hands, wrists, and elbows in a patient with chronic tophaceous gout of twenty-five years' duration. On both hands surgical excision of tophi was done. There was slow recurrence.

Fig. 2: Gout of the skin and olecranon bursa. This patient had uric acid crystals in the skin which appeared as white frosted areas.

Deposits may occur in the skin (Fig. 2) as a primary dermatitis rarely, or may more commonly involve the deeper layers of the skin.

The subcutaneous lesions often appear to have a capsule and are well circumscribed (Figs. 3-A, 3-B, and 3-C). Whether this is a true capsule, the result of proliferation of fibrous tissue in response to chemical inflammation, or compression of tissue by the tophi forming a false capsule has not been determined. These lesions are lobulated and fibrous strands are present throughout the confluent masses of sodium urate. Many subcutaneous lesions, however, appear to be infiltrating, particularly when the deeper structures are involved. It is thought that this infiltrative lesion is caused by rupture of the capsule through trauma or sudden tension caused by deposition of semiliquid urates. Probably both phenomena occur. However, the infiltrative lesions in our series arose in areas where there was little room for expansion, namely, the fingers and toes (Fig. 6). In no patient was invasion of muscle or nerve tissue observed, and there was a conspicuous absence of sensory disturbance except when major nerves were compressed. Digital nerves seem to escape compression even when surrounded by tophi.

Practically all of the bursal lesions that we removed were well confined to the bursa except where the bursa was firmly attached to bone or tendon. In one large bursa over the olecranon, there were small deposits of urate in the surface of the ulna necessitating

FIG. 3-A

FIG. 3-B

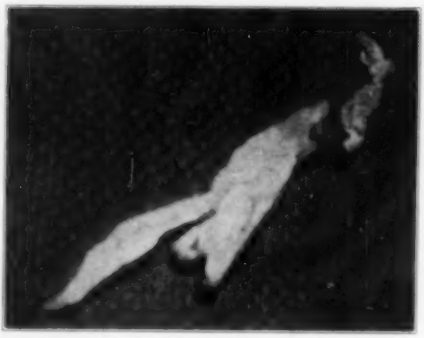

FIG. 3-C

Fig. 3-A: Well encapsulated lobulated lesion in the region of the olecranon. Note the irregular lobular structure. Each of these masses of urate was surrounded by a thin wall of fibrous tissue dividing the tophus into multiple compartments.

Fig. 3-B: The large olecranon bursa lies in the center of the photograph. This bursa contained the creamlike tophaceous material seen in the test tube and pan. An estimated six fluid ounces of material was present. This bursa had walls several millimeters thick containing firmer small tophi within the capsule.

Fig. 3-C: The flexor sublimis tendon was resected longitudinally to decompress the median nerve. In the photograph the infiltration of uric acid crystals and disruption of tendon fibers in the usual tendon lesion are shown.

removal of a thin layer of bone. In another patient, the patellar tendon was infiltrated over the anterior surface at the base of the prepatellar bursa.

Bursal deposits were often semiliquid (Fig. 3-B) and multilocular with separate compartments. The walls of the bursae were in several patients greatly thickened and firmer inspissated urate deposits formed in these walls as separate tophi.

Encapsulated lesions were not encountered in the tendons in our patients on whom surgery was done. The tophi were infiltrative with, in most cases, inspissated deposits in the interior and on the surface of the tendons (Fig. 3-C). The result of these deposits was a fusiform and irregular nodular enlargement of the tendon, interfering with the normal gliding action of the tendon in its compartment or sheath. On section, the tendon fibers were seen to be frayed and to have been replaced by tightly packed sodium urate crystals. The normal glistening appearance was absent and the color varied from light yellow to white in areas of crystal formation. Elasticity and tensile strength seemed to be considerably less than normal.

Joint lesions were typified by destruction of cartilage by direct deposition of crystals and by pannus formation. The cartilage, when incompletely destroyed, was the site of many small pits filled with urate crystals. The normal sheen was replaced by a dull frosting of crystals.

Pannus formation occurs about the margin of the articular cartilage. The pannus apparently destroys the cartilage by direct invasion and may perforate the cartilage and invade the underlying bone. Invasion of bone may also take place around the margin of the articular cartilage.

FIG. 4-A

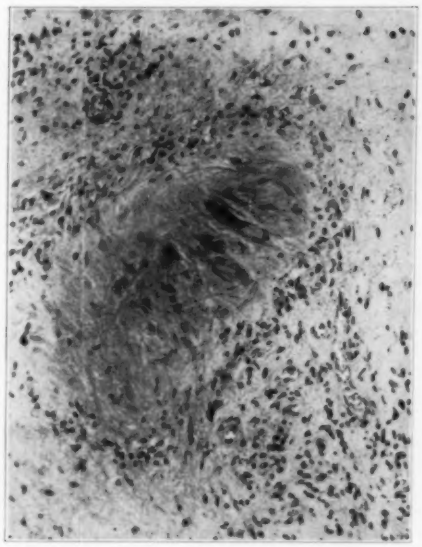

FIG. 4-B

Fig. 4-A: This tissue was removed from the forearm just distal to the olecranon bursa. Grossly the lesion was a firm nodule in the skin and subcutaneous tissues. Under low-power magnification a small, early tophus (in the lower portion of the photograph) was revealed.

Fig. 4-B: High-power photomicrograph shows the typical necrotic center with urate crystals. The zone of inflammatory cells consisted of a few giant cells, lymphocytes, and polymorphonuclear leukocytes. A beginning capsule might have been forming just outside the zone of inflammation.

Fig. 4-C: A mature tophus in this illustration demonstrates the fibrous capsule from another lesion. Compression of the adjacent tissues is evident. The uric acid crystals are deposited in clumps.

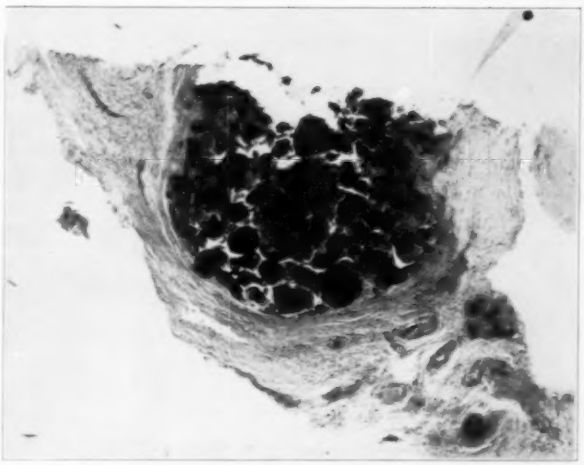

FIG. 4-C

When pannus destroys the cartilage, if there has been little bone destruction, fibrous ankylosis, later replaced by bony ankylosis, can occur [15]. This has occurred in our series.

If bone destruction is marked, and a large tophus forms at the end of the bone or across the joint, ankylosis may not occur; however, motion is usually limited by the tightly packed crystals (Figs. 26-A and 26-B).

Direct deposition of sodium urate may occur in the subchondral bone with cavitation as the normal trabeculae are destroyed (Figs. 5-A and 5-B). The combination of these two phenomena, deposition in bone and invasion by pannus, eventually destroys the normal architecture of the joint, leading to deformity.

Crystal invasion of the joint capsule and ligaments may occur from distension of the joint or a primary deposit. It is usually impossible in a destroyed joint to determine the origin of the lesion as all structures, including the capsule and overlying soft tissues,

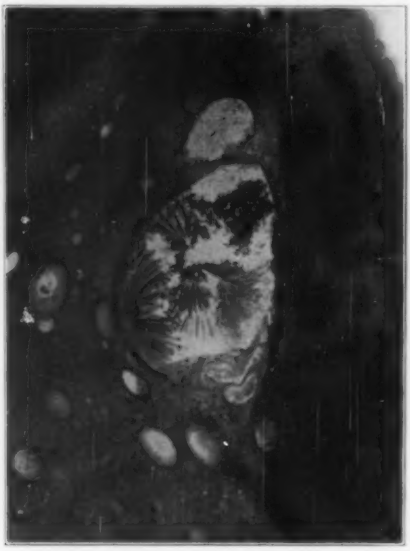

FIG. 5-A

FIG. 5-B

FIG. 5-C

Fig. 5-A: Low-power photomicrograph of a tophus in bone removed from the right sacro-iliac joint. Crystals of uric acid are deposited in the bone and apparently are adherent to the bone wall. Moderate cellular reaction is present in the space unoccupied by the tophus. Cavitation appears to be taking place by cellular activity about the tophus.

Fig. 5-B: High-power photomicrograph reveals the radiating crystals of uric acid about a central axis. Possibly this fundamental pattern accounts for the lobulated appearance, grossly, of many tophi.

Fig. 5-C: High-power photomicrograph reveals the typical crystalline structure of uric acid crystals.

are involved. Loss of elasticity and friability of the capsule and ligaments parallels that found in the tendons.

Bone destruction may occur in the shaft as well as the epiphyseal portion. Urate crystals form in the Haversian systems. Many lesions appeared to be expansile on the roentgenograms, having the appearance of enchondromata (Fig. 13). Minimal sclerosis was present and then only as a thin margin about parts of the lesions. The lesion is primarily a lytic one.

Microscopic sections of early lesions in the subcutaneous tissues or bursal walls revealed a central area of urate crystals and necrotic tissue (Figs. 4-A and 4-B), surrounded by an inflammatory wall of lymphocytes, monocytes, multinucleated giant cells, and polymorphonuclear leukocytes. Peripheral to this layer an area of fibrous stroma was present, forming a fibrous capsule.

The multinucleated giant cells often contain uric acid crystals which, in all probability, have been phagocytized.

The tophus apparently grows in size by deposition on the surface as the central portions are usually devoid of blood supply. As the tophus enlarges, the fibrous wall may thicken or invasion of the surrounding tissue occurs.

The physical properties and the time of growth of a tophus vary. The urate deposits may be in semiliquid to liquid form. This type is found primarily in bursae, but occasionally is encountered in subcutaneous tissues and in small amounts in tendons. Inspissated, firm or chalky deposits occur commonly and made up the majority of the lesions that were excised in our series. Apparently the location of the lesion as well as the length of time that the deposit has been present determines this physical property. However, occasionally a firm deposit has undergone apparent partial liquification.

The rate of growth of tophi varies from almost imperceptible enlargement, over months or years, to rapid expansion with distension of tissues to the point of necrosis of the overlying skin. In one of our patients, rapid enlargement with ulceration occurred in a period of eight months (Figs. 7-A and 7-B). Chemical composition of tophi is at present under investigation in the biochemical laboratory at Hines Veterans Administration Hospital. An analysis of three large tophi removed surgically is as follows: All surrounding connective tissue and fat were removed, as completely as possible, from a single large nodule of white, chalky material. The nodule appeared subdivided by trabeculae, which ran as septa subdividing the

FIG. 6

FIG. 7-A

FIG. 7-B

Fig. 6: Extensive tophus involving the middle finger. This lesion over the proximal interphalangeal joint is approaching rupture. This is a typical infiltrating lesion devoid of any demonstrable capsule.

Fig. 7-A: Tophi in the dorsal and palmar aspect of the index, middle, ring, and little fingers of the right hand. Tophi were also present in the flexor aspect of the middle and fifth digits of the left hand.

Fig. 7-B: This photograph of the lesion in the middle finger of the right hand illustrates the rapid formation of tophi which on occasion occurs. The photograph in Fig. 7-A was made eight months before. The finger now shows ulceration and necrosis of small skin areas and gross enlargement of the finger.

TABLE I

CHEMICAL COMPOSITION OF HUMAN TOPHI BASED ON 100 GRAMS OF DRY POWDER

Determination	E.W.H.	J.A.	L.B.P.
Uric acid [1]	48.21	49.20	24.52
Non-uric acid nitrogen [2]	1.30		
Sodium [3]	6.73	7.40	7.67
Chlorides as NaCl [4]	1.85	5.52	4.75
Potassium [5]	0.13		
Phosphorus [6]	0.26	0.35	0.73
Calcium [7]	0.04	1.54	0.66
Glucuronides [8]	0.14	0.27	0.31
Cholesterol [9]	6.46	6.50	5.92
	65.12	70.78	49.56
(Cholesterol esters %	63.10	30.2	30.9)

[1] Kern and Stransky: Biochem. Zeitschr. **290:** 419–427, 1937; modified by Archibald, Methods for Medical Laboratory Technicians, Department of the Army Technical Manual TM 8-227, pp. 232–234, 1951.

[2] Micro-Kjeldahl.

[3] Flame photometry (Perkin-Elmer).

[4] Sendroy, Colorimetric Chloride Analysis, J. Biol. Chem., **120:** 419–439, 1937.

[5] Flame photometry (Perkin-Elmer).

[6] Gomori's method.

[7] Wang, Calcium Determination in Biological Material, J. Biol. Chem., **111:** 443–453, 1935.

[8] Naphthoresorcinol method.

[9] Fisher, Manual of Standardized Procedures for Spectrophotometric Chemistry.

(Chemical analysis by Eugene Kanabrocki, B.S., Veterans Administration Hospital, Hines, Illinois.)

deposit into small masses. By means of a scalpel, the mass was reduced to small masses.

This matter was dried in a vacuum oven (room temperature) until a constant weight was obtained. Mortar grinding produced 75.45 per cent of fine (sifted through 200 mesh) white powder and 24.55 per cent of fiber.

The chemical composition of the fine, white powder from tophi removed from three patients was subjected to chemical analysis, results of which are listed in Table I; it can be seen that other elements make up the tophus as well as uric acid. The composition probably varies.

CIRCULATION

Arteriosclerosis may frequently accompany the disease so that necrosis of skin overlying a tophus may occur more readily, particularly in the feet. However, in many cases, although the skin and subcutaneous tissues and bone may be extensively involved, circulation is adequate. Even in areas of skin distension, there may be hyperaemia present during acute attacks with cyanosis present at other times.

Apparently the slow expansion of the lesion in most cases allows skin to accommodate to this increased pressure. This has been shown by infra-red photography of some of these lesions and has been confirmed at surgery (Fig. 8). A fine network of blood vessels is found in and just beneath the skin which apparently accounts for the survival of the skin even when extensive urate deposits occur. However, a time may come when the tophus slowly chokes off the blood supply and necrosis of the skin follows with ulceration. The base of the ulcer is made up of the tophaceous material.

In Figure 8, the circulation about the greatly enlarged olecranon bursa is adequate, as shown by infra-red photography. However, in the photograph of a finger (Fig. 9-A), even though the finger appears hyperaemic for the most part, pale areas in several regions of embarrassed blood supply are shown by infra-red photography. These areas ultimately ulcerated (Fig. 9-A).

FIG. 8

Infra-red photograph of the right olecranon bursa. The blood vessels overlying the bursa are located just below the skin as a complex network. Even though there was practically no subcutaneous tissue between the bursal wall and the skin, the blood vessels persisted apparently accommodating to the slow growth of the lesion.

It is because of local and general circulatory changes that the use of local anaesthesia or tourniquets about fingers and toes was avoided in our patients.

On occasion, sudden oedema of the feet may compromise the blood supply with fulminating breakdown of skin and tophi. This occurred in one of our patients on several occasions (Fig. 9-B).

A man, aged sixty-two, had gout for thirty years with extensive urate deposits in his feet coupled with arteriosclerosis. Each time that postural oedema or an exceptionally acute attack of elevated blood uric acid occurred, ulcers promptly formed with rather deep necrosis. Whether the sudden oedema alone or the sudden deposition of urates accounted for this necrosis was not clear. However, on several occasions, uric acid crystals frosted the skin about the areas of necrosis, which would indicate sudden deposition in the skin.

Ulceration with acute necrosis may resemble cellulitis. The surrounding tissue is erythematous and indurated, warm and tender to touch. These symptoms subside with the sloughing of skin and subcutaneous tissue and the discharge of urate crystals in a few days to a week. The ulcer than takes on the characteristic appearance of indolence with mild reaction in the tissues about a narrow margin adjacent to the borders. The base may be made up of urate crystals or necrotic tissue may be mixed with spotty areas of sodium urate. Urates are continually discharged with serosanguineous to purulent secretions. Ultimately, the base of the ulcer granulates and slowly the margins contract and epithelization of the area occurs eventually with minimal scarring. Occasionally, the ulcer may become almost completely inactive. The margins of the ulcer epithelize, a chalk-like deposit being exposed. The induration subsides in the surrounding tissues and the process of repair seems to halt for an indefinite period. This condition of exposed masses of sodium urate with little if any effort toward healing may last for many months. From these observations, one is led to believe that uric acid in pure form is relatively non-toxic

FIG. 9-A

Infra-red photograph of tophus in the middle finger of the right hand. Although the finger is in general hyperaemic, there are pale areas on the extensor surface over the area of maximum distension. These areas represent impaired blood supply and eventually ulcerated. Notice the engorged veins of the hand.

FIG. 9-B

Ulcerations are present just above the medial malleolus and anterior surface of the leg. A large necrotic ulcer has recently formed over the joint of the great toe. Necrotic tissue is still present in this lesion. Dry dermatitis is also evident.

in the tissues, and it may be that the sudden distension of tissues in the acute attack is more likely the source of pain and inflammatory reaction.

Spreading cellulitis was not encountered even in the acute necrosis of tissues. Although local cellulitis about the ulcers may have existed, the area of inflammation was usually smaller than that found in bacterial infection. It is difficult to distinguish bacterial inflammatory reaction from chemical or physically-incited inflammation in these cases.

Wound cultures have revealed the common skin organisms, *Staphylococcus aureus*,

Staphylococcus albus, and *Streptococcus hemolyticus*. In clean closed lesions, tophaceous material taken at operation showed no bacteria on culture. Abscess formation was rare and occurred in only two patients. Incision to increase drainage for purulent secretion accumulation was necessary in only one patient.

From these observations, we believe, as do others, that uric acid possesses a bacteriostatic action or that the area about the tophi has already established an inflammatory wall countering invasion of the surrounding tissues by bacteria.

OPERATIVE CASES

From 1947 to 1957, 280 patients having confirmed gout were admitted to Hines Hospital. Of these, twenty-one patients had tophi which were deemed satisfactory for surgery. Two other patients were treated at the Passavant Memorial Hospital. Thus a total of twenty-three patients were operated upon. All were male patients between the ages of thirty-six and seventy-six. The duration of symptoms varied from nine to thirty years. Tophi had been present for from three to twenty-four years. The number of operations varied from one to five per patient. One patient had seventeen operations and one patient had twenty-nine. The total number of operations was ninety-nine. Usually multiple tophi were removed at one operation, and often several tophi were excised through one incision.

There were forty-six operations on the upper extremity, fifty-two on the lower extremity and one biopsy of the sacro-iliac joint. In the majority of patients, the dorsal sides and volar aspects of the fingers and toes were involved by the tophus. Three operations were carried out about the knee joint; two of these were excisions of the prepatellar bursa. The knee joint was entered surgically in one case for biopsy. There was one surgical procedure on the right hip joint.

There were twenty-one operations on open lesions or ulcerated tophi. These were primarily curettage of exposed tophi in the base of these ulcers. There was one incision and drainage for accumulation of purulent secretion in a tophus which was the site of inadequate drainage.

There were seventy-eight operations on clean, closed tophi, and, of these, seventy-five healed by primary intention. Three wounds which sloughed either granulated and epithelized or skin-grafting was done. When sloughing of the wound occurred, an error of technique had been observed.

There were four excisions and curettages of tophi involving subcutaneous tissue only. Two involved subcutaneous tissue and tendons only, and the majority involved these structures as well as joint capsule, cartilage, and bone.

Six resections of joints were done. These were of the radial head, the distal portion of the ulna, the carpal lunate, and the proximal portion of the proximal phalanx of the toes. These operations were classified as arthroplasties, and, in addition, included one resection of the right femoral head with replacement by a metal intramedullary prosthesis.

Five joints were fused, including the subtalar and tibiotalar joints bilaterally in one patient. An open ankle fusion was done in one other. In all patients fusion occurred without difficulty.

There were two instances in which the median nerve was decompressed at the carpal tunnel by three operations. The first two were by division of the volar carpal ligament secondary to tophi in the flexor tendons at the wrist. In one instance, the tophi continued to enlarge in the right wrist and median-nerve symptoms recurred. This was treated by partial section of the flexor sublimis tendons by removal of half of each tendon longitudinally.

SURGICAL TECHNIQUE

We have divided the principles of surgical techniques into two main categories: excision of tophi in patients without ulcerated lesions and the management of ulcerated

lesions. These categories may be further subdivided into lesions involving the upper and lower extremities, as the problems of weight-bearing in the lower and dexterous movements in the upper dictate variations in principles.

In the excision of tophi in patients without ulceration and with intact skin, the general principles outlined in the following were adhered to.

Tourniquets were used primarily in the upper extremities. This was done by application of a blood-pressure cuff above the elbow with a pressure of 260 millimeters of mercury. The extremities were elevated for one minute to empty the blood vessels as much as possible before pressure was applied to the blood-pressure cuff. The tourniquet was released each hour for a few minutes, if the operation lasted more than one hour. In most cases, the tourniquet was released at the completion of the operation to check the viability of skin flaps, then reapplied to facilitate closure and to minimize hematoma formation before the dressings were applied.

Pneumatic tourniquets were used in all upper-extremity surgery. In one patient a tourniquet was used in the lower extremities.

FIG. 10-A

FIG. 10-B

The incisions commonly used in the hand and wrist. The incisions are located laterally for tophi involving the lateral aspect of the fingers as well as for tophi extending to the dorsal and palmar surfaces which are frequently encountered in large tophi. Transverse incisions may be made on the dorsum of the fingers and wrist when the tophus is primarily confined to this area. Similar incisions can be used on the palmar aspect over well localized tophi in the proximal and middle phalanges. Incisions in the web spaces are useful for tophi located over the metacarpophalangeal joints, but should be spaced between alternate fingers to prevent undermining a narrow flap of skin.

FIG. 11-A

FIG. 11-B

Fig. 11-A: Incisions at the finger tip may be made dorsal to the fat pad similar to the incision used for drainage of a felon. The fibrous tissue compartments are cut across for evacuation of tophi by curettage. At the wrist, flaps may be used to expose underlying tendons. The flexion creases are crossed by Z-shaped flaps when this is necessary. Good skin and subcutaneous tissue should be available when this incision is used.

Fig. 11-B: A flap longitudinally may be used over the olecranon, or this may be elliptical when excess skin is present over a large bursa to facilitate closure. Transverse incisions are permissible over small bursae.

FIG. 12-A

FIG. 12-B

Fig. 12-A: Tophus involving bone and subcutaneous tissues of the fifth digit. This finger was hyperaemic but moderate cyanosis was present at times.

Fig. 12-B: There was extensive skin necrosis. The two incisions on the opposite sides of the finger are to be condemned as blood supply is interrupted. If the tophus is extensive, a secondary operation is probably wiser after the first wound heals.

FIG. 13

Roentgenogram of the hand revealed extensive disruption of the joints with expansile lesions in the phalanges resembling enchondromata.

Tourniquets were not used in lower-extremity surgery in order to avoid damage to arteriosclerotic arteries, which were much more prevalent in the legs than in the arms. No tourniquets were used about the bases of fingers or toes for the same reason. No generalized gangrene of the upper extremities occurred secondary to the blood-pressure-cuff tourniquet.

Local anaesthesia was used in nineteen instances; the remaining operations were performed under general anaesthesia, local anaesthesia being used only in minor procedures. No spinal anaesthesia was used.

Local necrosis, when it occurred, could be attributed to faulty surgical technique or to local circulatory failure in skin flaps. In general, incisions were planned to interfere the least with blood supply (Figs. 10-A, 10-B, 11-A, and 11-B). When tophi were confined to the dorsum of the fingers and toes, transverse incisions over the area of maximum pointing of the tophus were made according to the advice of Linton and Talbott. This type of incision minimizes the flap area even when multiple transverse incisions are made, as each flap has a lateral base nourished by the digital arteries. Care must be exercised to avoid trauma to the laterally placed neurovascular bundle in the fingers and toes. With urate-crystal infiltration, these structures may be difficult to identify. One transverse incision on the dorsum of the hand appeared to heal, then opened following drainage of urates from the corner of the wound. Longitudinal incisions on the dorsal or ventral surface of fingers or toes were avoided following the general principle of not crossing flexion creases. Contractures in flexion or extension will develop as in other surgical procedures.

Laterally placed incisions posterior to the volar flexion creases, thus avoiding the neurovascular bundle, were used when the tophi were located laterally in toes or fingers, or when the tophus involved both the dorsal and ventral surfaces. Care must be exercised to avoid creating excessively deep or long skin flaps. It would seem more logical to remove extensive tophi in two stages rather than jeopardize the blood supply to a critical point. This is particularly true when gouty deposits completely surround the phalanges.

Longitudinal incisions on each side of the digit are to be avoided (Figs. 12-A and 12-B). In two patients in whom this procedure was done, sloughing of the dorsal skin resulted. Apparently, the narrow flap of dorsal skin has a precarious blood supply when tophi are extensive and the meager supply is completely severed by simultaneous incisions on the lateral aspect of the fingers or toes.

L-shaped flaps may be used, but only when there is adequate skin and subcutaneous tissue overlying the tophus. The incision is useful in the approach to tendons and joints in the wrist and hand when the tophi do not involve the subcutaneous fat.

Dissection of the skin and subcutaneous tissue must be by careful sharp dissection, with the scalpel directed against the tophus to avoid damage to the fine network of blood vessels in the deep layers of the skin. When well encapsulated lesions are excised, blunt dissection may seem feasible; however, cleavage planes are ill defined and there is a likelihood of rupturing the capsule and spilling urate crystals into surrounding healthy tissues. These crystals may act as foci for the formation of new tophi.

When tendons, ligaments, and joint capsules are the sites of deposits of urate crystals, sharp dissection can be carried out to a limited degree. Curettage with a small, sharp curette may be done, thus preserving many of the tendon and ligament fibers. The removal of the crystals is incomplete, but important tendons should be preserved.

Gentle handling of the skin flaps is essential (Figs. 14-A, 14-B, 14-C, 15-A, and 15-C). The skin covering a tophus may be paper-thin and easily torn and damaged by heavy retraction or pinching with tissue forceps. Linton advocated the use of suture retraction of these extremely fragile skin flaps. We have not followed this procedure, but have used very fine rake retractors with careful, gentle retraction. It is noteworthy that the wounds in the few patients operated on by the resident staff healed more slowly and with more reaction in the skin margins. Suture or mechanical retraction may be used if done gently.

FIG. 14-A

Tophaceous gout in various stages involving the fingers of both hands. The left middle finger was the site of semiliquid deposits which arose deep in the finger, but dissected the layers of the skin. The tophus was nearing spontaneous rupture. Pain was severe during this stage. A similar lesion was present on the right hand in the proximal phalanx of the index finger pointing to the ulnar aspect of the finger. A similar lesion was present in the little finger. The distal phalanx of the ring finger was the site of a hard inspissated deposit destroying most of the distal phalanx.

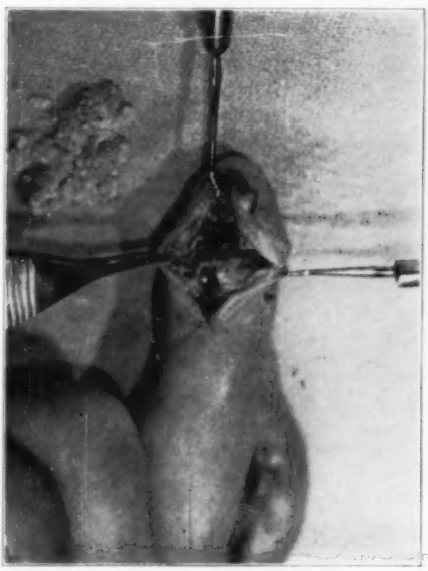

FIG. 14-B

FIG. 14-C

Fig. 14-B: The distal phalanx of ring finger at surgery. The tophus required curettage of the bone and soft tissues as the lesion was infiltrating. Practically all of the distal phalanx was destroyed. The chalk-like substance is to the left of the finger. The incision was similar to the approach used in draining a felon.

Fig. 14-C: Index finger was incised laterally just dorsal to the flexion crease. Semiliquid tophaceous material involved the subcutaneous tissues. Gentle handling preserved the skin.

FIG. 15-A

FIG. 15-B

Photographs show right hand two weeks postoperatively. The wounds healed by primary intention and there was no drainage. The distal phalanx of the ring finger was preserved and useful even with almost complete loss of the bone. No loss of sensation was noted. Pain was relieved and function improved moderately (same case as that in Fig. 14-A).

FIG. 15-C

Eight months after the operation, there was a recurrence of a tophus over the dorsum of the proximal interphalangeal joint of the index finger. There was slight radial deviation of the joint after surgery; moderate destruction of the joint accounted for this deformity.

Irrigation of the wound with isotonic saline solution was done routinely during the operation and before closure of the incision. Two purposes are served by this procedure. The urate deposits are mechanically washed from the deeper recesses of the wound and from inaccessible areas, and the drying of the surrounding soft tissues is avoided. These wounds seem to dry out rapidly when infiltrating lesions are encountered with urate crystals spread throughout the wound, increasing local tissue necrosis.

TABLE II

Patient	Age	Duration of Symptoms (*Years*)	Degree of Involvement	Region Involved	Types of Operation	Length of Observation	Recurrence
1. H. B.	44	11	Severe	Hands, wrists, feet, sacro-iliac joints, and elbows	Curettage Excision Decompression of carpal tunnel Resection of radial heads Biopsy of sacro-iliac joint Partial resection of wrist tendons	1948–1954	Yes
2. J. D.	57	10	Moderate	Hands and feet	Curettage	1 yr.	Unknown
3. A. F.	55	20	Severe	Hands and feet	Excision Curettage	1950–1954	
4. A. G.	49	14	Moderate	Hands, elbows, feet, and right hip	Arthroplasty, hip	1953 to present	
5. W. H.	38	14	Moderate	Great toes	Curettage	1951 to present	
6. E. H.	62	30	Severe	Hands, wrists, elbows, feet, and knees	Excision Curettage Excision of distal part of ulna Skin grafts	1953 to present	
7. C. L.	44	9	Moderate	Ankles	Excision	1949–1954	Unknown
8. W. McH.	34	7	Moderate	Knee, patellar tendon	Excision	1949–1950	Unknown
9. J. M.	62	32	Moderate	Hands and feet	Curettage	1952 to present	
10. J. N.	66	38	Severe	Hands and feet	Curettage Excision	1947 to present	
11. C. H.	75	42	Severe	Hands, wrists, elbows, feet, and knees	Amputation of rt. leg and fingers (elsewhere) Curettage	1947–1955	Yes
12. J. O'B.	65	9	Moderate	Feet	Excision	1947 to present	
13. L. P.	56	24	Moderate	Finger and olecranon bursa	Excision	1952–1956	
14. B. S.	61	26	Severe	Hands, wrists, elbow, feet, and knees	Curettage Excision Arthroplasty Decompression	1947 to present	Yes
15. A. S.	55	18	Moderate	Elbows, hands, and feet	Excision of olecranon	1947–1955	Unknown
16. W. S.	74	22	Moderate	Elbows, hands, and feet	Excision of olecranon	1947–1955	
17. L. R. S.	46	12	Severe	Hands and feet	Arthroplasty Curettage Excision	1949–1956	Unknown
18. F. T.	57	9	Moderate	Elbows and hands	Excision of olecranon	1948–1950	Unknown
19. F. V.	63	13	Moderate	Knees	Arthrotomy of knee Biopsy	1950–1956	Unknown
20. W. C.	54	27	Severe	Hands, wrists, elbows, feet, and knees	Excision Arthroplasty	1 yr.	Unknown
21. V. F.	70	4	Moderate	Knees	Biopsy	1951–1955	Unknown
22. J. K. S.			Severe	Hand, elbows, and feet	Arthrodesis of ankle		
23. N. U. C.			Severe	Feet and hands	Skin graft		Unknown

FIG. 16-A

FIG. 16-B

FIG. 16-C

Fig. 16-A: Roentgenogram of both feet in which Keller bunionectomies had been done. The left reveals bone fusion of the metatarsophalangeal joint. The right was not bridged by bone.

Figs. 16-B and 16-C: The feet as they have appeared on several occasions when ulceration developed from necrosis of skin over small tophi.

Bone and cartilage lesions usually require thorough curettement for removal of as much urate as possible except when resection of a complete lesion is practical (Table II).

Extensive stripping of the periosteum when this structure can be identified should be avoided. The blood supply to a bone packed with urate crystals may be precarious. A window may be made in the bone at the point of penetration of the tophus and curettage of the cavity carried out. Saucerization of the bone is usually not necessary. In no patient have we packed the cavity with bone or done any bone-grafting. However, it would seem logical to do this in a patient in whom there was evidence of adequate response to uricosuric agents. If the urates in the tophi can be absorbed in time, bone-grafting of defects would be most useful in hastening the restoration of the involved bones.

Certain areas are particularly adaptable to resection of the joint surfaces. The most useful area is about the great toe. The Keller procedure with excision of the exostosis has been successful in re-establishing motion and eliminating pain. In one of our patients, this procedure gave relief of symptoms for several years. However, bony ankylosis has occurred in one foot and further resection is now considered (Figs. 16-A, 16-B, and 16-C).

Indications for resection of other joints parallel the indications for resection of these joints in other conditions. The radial head, distal portion of the ulna, and proximal

FIG. 17-A

Hypertrophic changes in the left elbow of a patient who had urate deposits in the joint with cartilage destruction. Flexion and extension were limited and painful.

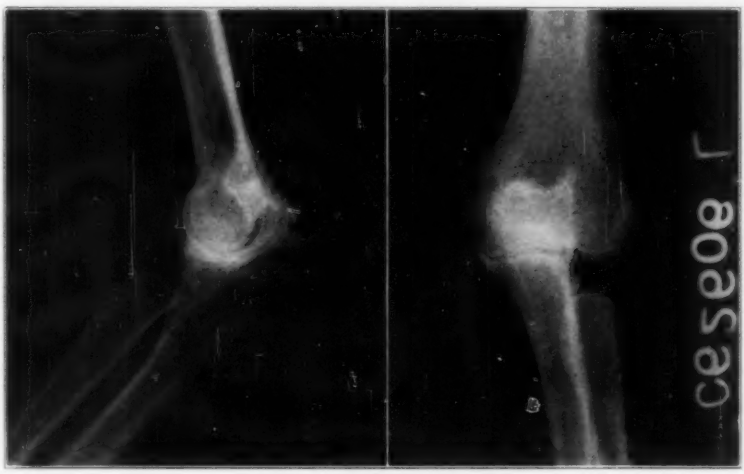

FIG. 17-B

An arthroplasty was done with resection of the radial head and removal of excess bone about the olecranon and olecranon fossa. Pain was relieved but there was little change in joint motion.

phalanges of the toes may be resected with moderate improvement of function and diminution of pain (Figs. 17-A and 17-B).

Closure of clean wounds was done with minimal subcutaneous sutures and in the majority of cases with skin closure only. Interrupted and continuous sutures have been used without striking difference in wound healing. Drainage was avoided and did not seem necessary in patients without ulceration and intact skin. No extensive postoperative hematomata developed, and sepsis did not occur except locally in the few wounds in which necrosis occurred.

We have observed discharge of semiliquid tophaceous material from several wounds at the time of the first dressing when at surgery only dry, chalky deposits were observed.

FIG. 18-A

Tophi over the distal phalanges of the index and middle finger of the right hand.

FIG. 18-B

Fig. 18-B: Wounds ten days after operation. The tophus at surgery had been hard and chalk-like invading the extensor tendon insertion. The wound was dry at closure. At this dressing the wound was distended by semi-liquid tophaceous material which exuded from the wound when pressure was exerted over the flap.

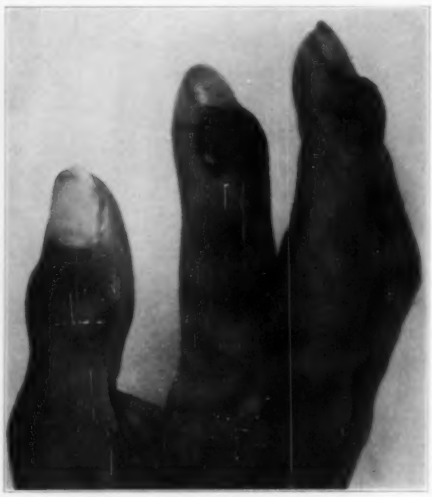

FIG. 18-C

Fig. 18-C: The wounds healed without inflammatory reaction or sloughing shortly after this.

Whether this represents liquefication of remaining tophaceous material, or new deposits, we have been unable to determine (Figs. 18-A to 18-D).

Pressure dressings were applied routinely. A moist, coarse, gauze dressing was placed smoothly over the wound and covered by voluminous fluff gauze. The whole was covered by elastic bandages to exert moderate firm pressure. The pressure dressing tends to minimize oedema and the formation of hematomata and aids in the elimination of dead spaces under the skin flaps. The moist dressing helps to conduct secretions away from the wound during the immediate postoperative period.

Splinting of the part in the position of function of the hands and feet was done after stiffening of the fingers in extension developed in one patient. Splints were made of voluminous pressure dressings, plaster molds, or metal. A particularly useful splint has been the Mason-Allen splint in the hand and forearm. This splint holds the hand and wrist

FIG. 18-D

The fingers three months after operation. Recurrence eventually became evident.

in the position of function so that disability is lessened should limited motion follow surgery.

The management of upper-extremity and lower-extremity lesions differs as it does in other conditions. In the hand, every effort should be made to preserve vital structures, including soft-tissue covering, nerves, tendons, and bone. If these structures are preserved and the hand is placed in the position of function (that is, as though the fingers were grasping a large ball) the disability of lost motion will be minimized. Since uricosuric

FIG. 19-A

FIG. 19-B

FIG. 19-C

Fig. 19-A: Amputation had been done below the knee in the left leg prior to admission to our service for chronic draining ulcers secondary to tophi involving the foot. Small tophi were present in the stump.

Fig. 19-B: The right foot was the site of a chronic dermatitis with several indolent ulcers present on the dorsum and lateral aspect of the foot. Subcutaneous tophi were present over the tibia in the right leg.

Fig. 19-C: This patient was carefully fitted with a below-the-knee prosthesis.

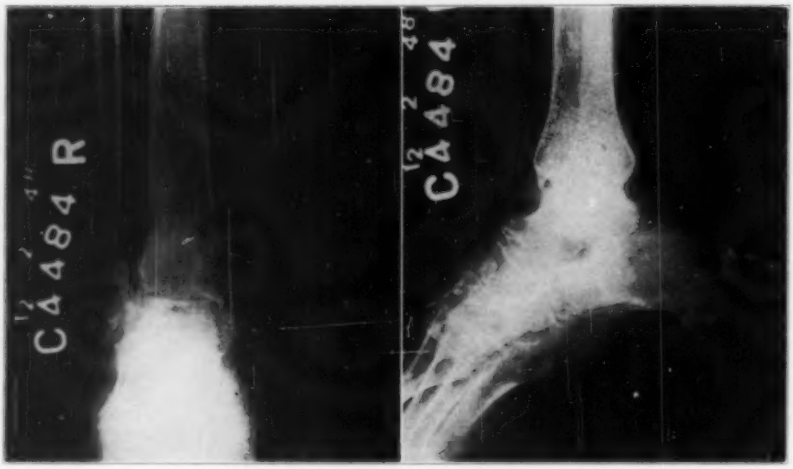

FIG. 20

Chronic tophaceous gout of the tibiotalar and talocalcaneal joints. Roentgenograms showed extensive destructive joint changes. Pain and limitation of motion prevented the patient from walking but a few steps at a time.

agents hold some promise of controlling the progression of this disease, radical excision of vital parts should be minimized.

The lower extremity poses the problem of flexible, yet stable weight-bearing. Dexterous movements of the toes are not essential.

Amputation of toes was done in only one of our patients. In this patient, a fifth toe was the site of extensive urate deposits. The bones were completely destroyed, leaving a greatly distended toe composed primarily of tophus and skin. After removal of the tophus and healing of the wound, a small skin nubbin remained. This structure was constantly out of place when stockings and footgear were used. Usually the toe was laterally displaced by the stocking and irritation developed when a shoe was worn. At the request of the patient, the toe was amputated by an elliptical incision at the base. Toe amputations have been reported in the literature, and there has been little loss of function of the foot. We have preferred to preserve the toes whenever possible.

One patient in our series had a major amputation for extensive gout of the left foot prior to entering Hines Veterans Administration Hospital (Figs. 19-A, 19-B, and 19-C). He also had several amputations of parts of the fingers in past years. The hands were almost completely rigid; however, he was able to feed himself and take care of his own hygiene fairly well. The amputation stump below the knee contained several small tophi. With careful fitting by the limb-maker, he was able to wear with comfort a below-the-knee prosthesis. If tophi interfere with the wearing of the prosthesis in the future, they will be excised. To date, the wearing of the prosthesis has not caused trouble in the stump, and the tophi have not changed in size or appearance.

Five joints were fused surgically in this series (Fig. 20). In one patient, bilateral subtalar and ankle-joint fusions were done by driving a three-flanged nail across the joints from the plantar surface of the calcaneus into the tibia. Fusion occurred without difficulty after a period of four months. Narrowing of the joint spaces was seen on the roentgenogram. The patient was incapable of walking more than a few steps because of pain. Since there were no large tophi in the tibia, talus, or calcaneus, it was judged that fusion would take place as the pannus destroyed the cartilage. This eventually occurred.

A fifth joint was fused at the tibiotalar joint through an anterior incision. This joint was the site of a large tophus involving the lower tibial articular surface. Curettage was

FIG. 21-A

Roentgenogram of the pelvis showing destructive lesions in the head of the femur and acetabulum which are primarily cystic with moderate sclerosis. There is loss of joint space.

FIG. 21-B

An intramedullary-stem prosthesis was used to replace the resected femoral head.

done on the urate deposits and the remaining cartilage and subchondral bone was removed. Plaster fixation resulted in fusion of the joint in five months (James K. Stack's patient). Both of these patients have been free of pain in the fused joints since operation.

Because of the nature of the pathological changes, it would seem logical that simple fixation internally or externally would result in fusion if the joint surfaces are involved with pannus. If a large tophus has destroyed the joint, and the joint is packed with urate

FIG. 22-A

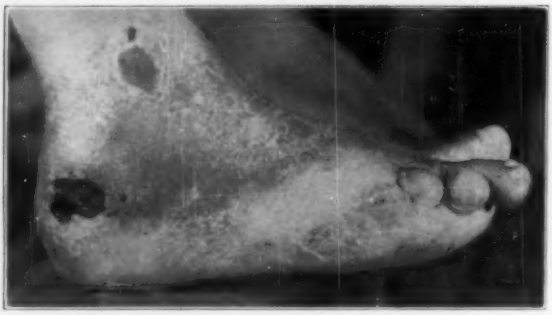

FIG. 22-B

Fig. 22-A: Feet of a patient with gout of many years' duration. Note the small ulcerated area over the right heel.

Fig. 22-B: The lesion suddenly enlarged during an acute attack of gout and oedema of the feet. The ulcer at this stage was indolent with little reaction about the margins of the ulcer. The condition remained static for many weeks before healing.

deposits, holding the bone surfaces apart, it seems logical to remove the deposit and fit the bone surfaces together.

Keller bunionectomies have been done in several instances as cited elsewhere in this paper and have proved useful.

One resection of the femoral head was done in this series, and the bone replaced with an intramedullary-type prosthesis (Figs. 21-A and 21-B). This is the only patient in whom definite destruction of a hip joint by gout was observed in our series. The man had had progressive loss of motion with pain in the hip for seven years. Roentgenograms showed destructive changes in the head of the femur, loss of joint space, and a cystic lesion in the acetabular roof, similar to advanced changes observed in osteo-arthritis. About 40 per cent of hip motion was present. Six months after surgery which had included excision of the head and neck of the femur and curettement of the acetabulum, the patient regained

FIG. 23-A

FIG. 23-B

Fig. 23-A: A few small indolent ulcers are present over the dorsal surfaces of the feet.

Fig. 23-B: Roentgenogram of the right foot revealed the advanced changes of destructive tophaceous gout in the bones and joints. The lesions are lytic and in some areas expansile with only a thin shell of bone remaining. Minimal sclerosis is present about the lesion in the first metatarsal.

FIG. 23-C

FIG. 23-D

Fig. 23-C: During an acute attack of gout associated with oedema of the feet and legs, fulminating necrosis of the skin of the feet occurred. The white discolorations seen in the photograph are urate crystals deposited in the skin. Preceding this attack, pruritus of the legs was marked for ten days. This subsided with the attack.

Fig. 23-D: Plantar necrosis in a lesion similar to those occurring on the dorsum of the foot.

20 per cent of the hip motion lost and had about 60 per cent of normal hip motion with only mild pain in the hip on the extremes of motion and prolonged weight-bearing. Since the roof of the acetabulum was the site of a tophus, the prosthesis may in time migrate into this area. Six months after operation no such change occurred.

Ulceration of the skin overlying tophi is a frequent occurrence (Figs. 22-A and 22-B). These ulcers usually occurred on the dorsum of the fingers and toes and the lateral aspect of the foot and leg in our series. The soft-tissue inflammatory reaction varied considerably about these ulcers, and seemed to be related to the duration of the ulcer as described elsewhere in this report. Surface infection and surrounding local cellulitis was not a major problem. During the acute necrosis phase, warm, moist dressings were applied to promote discharge of urate crystals and to control inflammatory reaction (Figs. 23-A, 23-B, 23-C, and 23-D). The extremity was elevated. When the oedema had subsided in a week or two, the ulcers became indolent and spontaneous healing was delayed until the urate deposits had been completely discharged. At this stage, curettage of the ulcer may be done. However, the underlying tophus is usually extensive, only a small portion showing in the base of the ulcer. The tophus may be approached through this opening and the opening enlarged with a transverse incision. In two patients, when counter-incisions were made away from the ulcer margin, necrosis of the intervening skin followed. From this experience, we feel that counter-incisions should be avoided and the tophus evacuated through the base of the ulcer. Spreading cellulitis or septicaemia did not occur in our patients following this procedure.

FIG. 24-A

FIG. 24-B

Fig. 24-A: Preoperative appearance of a large tophus on the great toe. The bone and extensor tendons were infiltrated. A smaller ulcerating lesion was present in the fourth toe with urates appearing as white areas in the base of the ulcers.

Fig. 24-B: Postoperative appearance of the toes after excision and curettage of the lesions.

The wounds were packed open with a minimum amount of petrolatum gauze and warm, moist saline dressings were applied. Excessive application of heat was avoided in order to prevent further circulatory embarrassment. The extremities were elevated for several weeks postoperatively. Following this procedure, the wounds closed slowly discharging the remaining uric acid crystals that were almost invariably incompletely removed by curettage.

Skin-grafting was done in three patients. Two had lesions on the fingers and one on the lateral aspect of the forearm. The grafts grew well when they were applied to healthy granulation tissue. Wounds will not epithelize, however, until all urates in the base of the ulcer have been discharged. This was particularly striking in a transverse surgical wound on the dorsum of the hand which became necrotic. This wound eventually healed by secondary intention with minimal scarring. However, this did not take place for approximately six weeks until all urates were discharged and the wound had granulated completely.

MANAGEMENT OF THE PATIENT BEFORE AND AFTER OPERATION

Preoperative management of these patients was under the direction of the Medical Service at the Hines Veterans Administration Hospital.

Before the introduction of probenecid, the patients were treated with sodium salicylate several days before surgery, the dosage per day varying from sixty to 120 grains; colchicine (grain 1/120) was administered three times a day. Postoperatively, this regimen was continued for one week.

During the past three years, the patients have been given probenecid, 0.5 gram to three grams per day, throughout their hospital stay and whenever possible as out-patients.

FIG. 25

This patient had excisions of large tophi from the bursae over the ischial tuberosities several years prior to admission to Hines Veterans Administration Hospital. No recurrence has been manifested.

Colchicine has been given three days before and for one week postoperatively, 1/120 grain three times a day.

This regimen of probenecid and colchicine has minimized postoperative acute attacks of gout. Without colchicine, postoperative acute attacks are the rule rather than the exception in our experience as well as in the series of cases reported by Linton and Talbott.

FOLLOW-UP STUDIES

Four patients have died during the past five years. One had no recurrence of tophi nine months after removal. One had no recurrence of gouty olecranon bursitis after seven years, and one had continuing recurrences of each tophus removed. This last patient had poor kidney function and uric acid excretion was not increased on probenecid. One patient had no recurrence for one year before death. One patient, under regular observation, had slow recurrence of all resected tophi, varying from six months to six years. This patient had regular attacks of acute gouty arthritis, and had multiple tophi. He was given probenecid only when hospitalized and he abstained from the drug when away from the hospital.

Five patients have been lost to follow-up. The remaining patients have had no recurrences over a period varying from six months to six years. In each instance of recurrence, there had been incomplete surgical removal of the lesion or the patient did not respond to probenecid, or he did not take the drug routinely. No patient regained normal function when joints or tendons were involved; however, all had moderate to complete relief of pain between acute attacks of gout. Disability was lessened in varying degrees in all patients.

SUMMARY

In 10 per cent of patients with gout, tophi form; these may destroy skin, tendons, ligaments, and the skeletal structures. Since the disease may ultimately disable the

FIG. 26-A

FIG. 26-B

Fig. 26-A: Roentgenogram shows destruction of the first metatarsal bone and joint.
Fig. 26-B: The dorsal area of the foot was grossly distended with tophaceous deposits involving the skin, subcutaneous tissue, tendons, and bone and joints.

musculoskeletal system, if improperly treated, the management of these patients should be the combined responsibility of the internist and the orthopaedic surgeon.

Early diagnosis and prompt treatment can prevent severe crippling. In patients in whom the disease has been neglected tophaceous destruction of musculoskeletal structures may be helped by carefully selected surgical procedures.

The pathological process is one of invasion and destruction of skin, ligament, tendon, cartilage, and bone by deposition of urates. This process is accompanied by an acute or chronic inflammatory response at the site of involvement. Lesions may be encapsulated in bursae and subcutaneous tissue and infiltrative in skin, tendon, and bone.

Tophi may form rapidly or slowly and physical properties vary from semiliquid to inspissated, chalk-like deposits. The distribution of lesions is primarily distal in the extremities with a predilection for the extensor surfaces. Blood vessels may be involved in the process to a moderate degree, but nerves and muscles are apparently affected by pressure phenomena rather than invasion or deposition of urates.

We believe surgical intervention is warranted in the following conditions found in chronic tophaceous gout: (1) when tophi are unsightly; (2) when tophi are painful; (3) when tophi interfere with tendon function; (4) when tophi threaten to cause skin necrosis and ulceration; (5) when tophi have ulcerated or sinuses are present; (6) when tophi encroach upon nerves causing symptoms of compression; (7) when joints are being destroyed and are painful; and (8) when the total amount of urates in the body can be lowered by excision of readily accessible large tophi.

Sodium urate and uric acid seem to possess bacteriostatic properties so that sepsis is usually mild and well localized when present.

Circulation may be impaired by tophi when distension of the tissues is marked, although the skin survives remarkably well until late in the process. Arteriosclerosis is commonly present in the lower extremities in the older patients. These factors demand specialized surgical technique.

The pneumatic tourniquet may be used in the upper extremity, but should be used cautiously in the lower extremity. Local tourniquets should not be used about fingers or toes.

General anaesthesia is preferable to local anaesthesia except for minor excisions of superficial tophi. Distension of tissues with the local anaesthetic agent may impair the blood supply and cause necrosis of skin.

Incisions in general should parallel the blood supply of the part. Counter-incisions in the fingers and toes should be avoided as necrosis of the intervening skin may result. Sharp dissection is preferred when it is feasible, but curettage may be done in infiltrative lesions to remove the maximum amount of urates while preserving essential structures.

Gentle handling of tissues is necessary to preserve the blood supply. Wounds should be irrigated to prevent necrosis of tissue from drying and to mechanically aid in removal of the tophi.

Resection of joints, arthroplasty, and arthrodesis of painful joints may lessen pain and improve function to a limited degree. Curettage or partial resection of tendons may help preserve function.

Skin-grafting may hasten healing of ulcerated lesions after removal of the gouty deposits when granulation tissue appears.

Infection is not a serious problem and the general principles of treating infections apply to gout with addition of the medical management peculiar to gout.

Minimal suturing of wounds is advisable in order to preserve blood supply and to allow escape of liquified deposits following surgery when removal of the tophus is incomplete.

Pressure dressings and splints minimize dead space, help prevent hematomata, and put the parts at rest so that healing may occur.

Prolonged splinting is to be avoided as ankylosis may occur.

Amputation of toes may be necessary, but every effort should be made to preserve the fingers.

A definite plan of preoperative and postoperative medical management helps to prevent complications and acute attacks following surgery.

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Dupuytren's Contracture

With Special Reference to Pathology*

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Dupuytren's contracture, first described by Plater in 1614, was reported in 1823 by Astley Cooper. In 1832 Dupuytren described the dissection of a hand with contracture of the palmar aponeurosis and recommended division of the contracted bands. For a review of the anatomy of the palmar fascia, the reader is referred to the works of Kanavel, Koch, and Mason, Harper, Skoog, and Kaplan.

This paper is based upon our experience with ninety-nine patients who had Dupuytren's contracture. Bunnell summarized the reported incidence of Dupuytren's contracture in the general population, estimating that the disease occurs in, roughly, 1 to 2 per cent of the population. We found that the contracture is encountered more frequently in the older age groups. Among our patients there was one between the ages of ten and nineteen years (a twelve-year-old girl); three, between the ages of twenty and twenty-nine; eight, between the ages of thirty and thirty-nine; eighteen, between the ages of forty and forty-nine; forty, between the ages of fifty and fifty-nine; twenty-two, between the ages of sixty and sixty-nine; and seven, between the ages of seventy and seventy-nine. This age distribution agrees well with the statistics published by Skoog, Conway, Boyes, Graubard, James and Tubiana, and many others. Two in this series, one man and one woman, were Negro; the remainder were Caucasian.

As indicated in Table I, the contracture is more common in the right hand than in the left hand, and is more commonly bilateral than unilateral. The contracture may also occur in the plantar aponeurosis [44]; only five of our patients were so affected. The ulnar side of the hand is most often involved in Dupuytren's contracture. Table I shows the agreement between the present series and the collected series of Skoog. He collected 2,278 cases from the literature. One thousand, two hundred and fifty-one (55 per cent) had bilateral contracture; 663 (29 per cent) had the right hand only involved; and 364 (16 per cent) had only the left hand involved. In this same group the thumb was involved seventy-three times; the index finger, 123 times; the middle finger, 536 times; the ring finger, 1,451 times; and the little finger, 1,217 times.

In our series there were seventy-nine men and twenty women, a ratio of approximately four to one. In most reported series the ratio has been about eight to one. We have no explanation for the higher proportion of women in our group of patients.

The earliest recognizable stage of Dupuytren's contracture is a nodule in the palm, usually located in line with the ring finger, and most often at the distal palmar crease. The nodule is painless and does not limit the function of the hand. The skin is attached intimately to the nodule. As the disease progresses more nodules appear which gradually become organized into one or more contracted longitudinal bands. These bands gradually draw the metacarpophalangeal joints and proximal interphalangeal joints into flexion. The distal interphalangeal joints are not involved. The rate at which the contracture progresses is quite variable; in some patients a severe contracture develops in only a few months, while in others, the same degree of disability may not be present for years. The progress of the disease may be arrested spontaneously at any stage. We do not know any way to predict the course of the disease in an individual patient.

* Read in part at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 25, 1957.

TABLE I

INCIDENCE OF DUPUYTREN'S CONTRACTURE

Location	Present Series		Skoog's Reported Series	
	(*No.*)	(*Per cent*)	(*No.*)	(*Per cent*)
Right hand	29	29	663	29
Left hand	24	24	364	16
Both hands	46	46	1,251	55
Little finger	72	73	1,217	53
Ring finger	75	76	1,451	64
Middle finger	28	28	536	24
Index finger	10	10	123	5
Thumb	15	15	73	3
Palmar nodules only	32	32		

REVIEW OF THE LITERATURE

Etiology

The etiology of Dupuytren's contracture is unknown. Dupuytren thought it due to repeated trauma; recently authors have felt that trauma is not an important factor. Moorhead has stated this view unequivocally. In our series of patients there were fifty-four who had never done manual labor of any kind. Eight patients had occupations which required occasional moderately heavy use of their hands. The remaining thirty-seven were laborers. On the basis of these figures we agree with the series reported by Kanavel, Koch, and Mason, in which they found that Dupuytren's contracture was more apt to be encountered in patients who did not perform manual labor.

Other diseases which have been related etiologically to Dupuytren's contracture include neuropathy, both peripheral and central, disorders of the sympathetic nervous system, neurosyphilis, gout, rheumatism, disorders of the endocrine system, such as diabetes, deficiencies of the thyroid and pituitary glands, tuberculosis, various chronic intoxications, local infections, epilepsy, and coronary-artery disease. None of our patients had any of these diseases except that one had diabetes and another, epilepsy.

The majority of authors agree that heredity is involved in some cases of Dupuytren's contracture. Schröder reported that ten of his thirty patients had relatives with the contracture. Skoog reported a positive hereditary history in twenty-two of his fifty cases. In our series eight patients had relatives with the disease. Many of our patients were Americans of the first or second generation who had no knowledge of their relatives overseas.

Gross Pathology

The pathological changes observed in Dupuytren's contracture have been described by several authors. Dupuytren himself described the macroscopic changes in the palmar aponeurosis. He described shortening and retraction of the palmar fascia and noted bands of contracted fascia passing into the affected fingers. Today there is little argument that the disease does involve the palmar fascia, although some consider that the palmar fascia is secondarily involved in an inflammatory process which arises in the interstitial tissues of the hand. Kanavel, Koch, and Mason concisely described the relationship between the palmar fascia and the digital fascia. They observed that the pretendinous bands of the palmar fascia pass into the superficial digital fascia. The vertical septa which lie between the tendons and neurovascular bundles of the palm pass into the deep digital fascia. These fascial fibers passing from the palm into the fingers ultimately attach to the sides of the proximal and middle phalanges. Kaplan in 1938 observed flexion of the proximal and at times of the middle phalanges when the pretendinous bands of the palmar aponeurosis

were pulled. Flexion of the phalanges did not occur in those hands in which no pretendinous bands passing into the fingers could be identified. He concluded that the flexion contracture of the phalanges in Dupuytren's contracture depended upon the contracture of the phalangeal insertion of the pretendinous bands. Richer in 1877 described the hard thickened short fascia, which he felt resulted from an increase in the size and number of elastic and collagen fibers. He did not note any inflammation.

Our gross observations are as follows. The hard nodules and bandlike areas lie within the palmar aponeurosis. In many areas the skin is intimately attached to the thickened palmar fascia. At times the skin is so firmly bound to the fascia that the two cannot be separated except by creating an artificial dissection plane with a scalpel. Occasionally such skin is of necessity excised. These areas of firm attachment between the skin and the fascia are most often noticed at the distal flexion crease of the palm, or in the flexion creases of the fingers, where adipose tissue is normally scanty.

The nodules and bands vary in appearance. These variations appear to coincide with the stage of maturity of the contracture in that particular area. The younger tissue is gray white and softer than the more mature tissue. The gray-white areas, often in nodular form, do not have distinct margins. Rather, small projections appear to pass from them into the surrounding interstitial tissue and fat. The more mature tissue, which is usually arranged in dense contracted bands, varies from white to yellow. The surface is glistening, and in very dense contracted areas, even has a translucent glary appearance. Usually the distal palmar and digital fascia is more involved than that in the proximal portion of the palm. We have, however, had several patients in whom one or more prominent bands of contracted fascia ran proximally as far as the transverse carpal ligament.

The proliferative and contracted stages of the disease may involve any of the vertical septa which pass from the palmar aponeurosis to the deep or pre-osseous fascia. Tendons, vessels, and nerves may be surrounded or angulated by these masses of tissue. In no instance did we note invasion of the sheaths of the flexor tendons. Nerves may pass through a mass of diseased fascia, but the nerve appears to have been surrounded rather than invaded, since it can always be freed from the contracted fascia by careful dissection. In the fingers the disease appears to involve only the digital fascia of the proximal and middle phalanges. Flexion contracture of the distal interphalangeal joint or extension of the disease beyond the proximal one-half of the middle phalanx was not observed in our patients. Occasionally, the distal interphalangeal joint may be hyperextended or even dislocated dorsally. This is usually seen in severe contractures if the patient has been forcing a tool between the palm and the contracted finger.

Microscopic Pathology

There has been little disagreement about the gross changes in Dupuytren's contracture. The major dissension today concerns the description of the microscopic changes, and in particular, the interpretation which is placed upon these changes. Although earlier observations of the histopathology of Dupuytren's contracture were reported, Langhans in 1887 provided the first exact description of the microscopic changes in this disease. He wrote that the histological changes at this site are essentially a process of new formation [of tissue] which runs off into the existing connective tissue. The cells of the aponeurosis and of the vascular sheaths are considerably increased in number and size.

Anderson in 1891 described hyperplasia of connective tissue which he believed was an inflammatory response. This process was considered to have begun in the fatty and fibrous tissue of the subcutaneous layer, then involving the palmar fascia by migrating along the blood vessels. Nichols in 1899 described his microscopic observations. He also interpreted the disease as connective-tissue hyperplasia.

Janssen in 1902 described fibrous-tissue proliferation arising from multiple foci. He pointed out the microscopic similarity between the proliferating fibrous tissue of

Dupuytren's contracture and that of fibrosarcoma. He concluded that the disease was proliferative, but neither inflammatory nor neoplastic. He felt that the disease could not be considered fibroma because of its diffuse and widespread distribution. Davis and Finesilver recorded a translation of Janssen's conclusions: "braidlike hypertrophy of the connective tissue, which originates in the walls of the smallest vessels and which ends in contraction." Coenen in 1918 wrote that the disease was due to a chronic inflammation, while Ledderhose in 1897 and again in 1920 described the fibrous-tissue proliferation, but did not consider it inflammatory.

Krogius in 1920 advanced the theory that Dupuytren's contracture is due to growth and contracture of the remnants of primitive embryonic muscles, the flexores breves manus superficiales. This theory has never been supported. Skoog in 1948 reviewed the embryology of the palmar fascia. He was unable to find any suggestions of primitive muscle developing in the palmar aponeurosis.

Iklé in 1928 rarely observed signs of inflammation, in the form of lymphocytic infiltration. He described the fibrous-tissue proliferation and noted the suggestion of neoplasm. He felt that the lesion was neither neoplastic nor inflammatory. Iklé concluded that the disease was a chronic hypertrophy of fibrous tissue resulting in fibrosis of the palmar fascia. Boehme observed definite development of thick-walled capillaries resembling angiomatous tissue, relaxation of the elastic fibers, and endothelial changes in the small veins.

Meyerding and associates in 1941 recorded their observations on specimens of the palmar fascia in sixty-one cases of Dupuytren's contracture in fifty-seven patients. In all cases in which overlying skin was available definite pathological changes were noted in it, and in the early stage, before any contracture occurred, the skin was bound down tightly. The changes in the skin were chiefly in the reticular and papillary zones where increased connective tissue was noted. Sweat glands were surrounded by fibrous tissue and lymphocytes in less advanced cases, but in advanced cases, they were rare or absent. In twenty-four of their fifty-seven patients there was "definite lymphocytic infiltration of the skin or subcutaneous tissue." Infiltration was noted to precede fibrosis. The lymphocytes and new capillaries were more numerous in the areas of unchanged fat cells. New capillaries and perivascular inflammation were almost entirely lacking in the palmar fascia itself. On the basis of these observations Meyerding concluded that the disease began as a perivascular inflammation in the interstitial tissues of the palm, and secondarily involved all of the structures of the palm, including the palmar fascia.

Horwitz in 1942 reported histological examinations in thirty-five cases of Dupuytren's contracture. He concluded that the disease was a benign fibroplasia of the palmar connective tissues. Clay in 1944 concluded that the disease is a neoplasm—a fibroma of the palmar fascia. Broadbent in 1955 described enlargement of pacinian corpuscles in hands affected by Dupuytren's contracture. Reflex neurovascular changes in the hand associated with enlarged pacinian corpuscles were considered to be of interest, but no definite etiological theory was advanced. Skoog, in 1948, in his classic monograph on Dupuytren's contracture, summarized the most prominent pathological descriptions in the literature and added his own observations. He examined twenty-nine specimens. In addition, electron microscopy was carried out on nine specimens. The nodules of hypercellular connective tissue were regarded as the initial stage of the disease and as pathognomonic for it. At the site of new-nodule formation rupture of aponeurotic fibers was found. Iron pigment was found in the cellular areas. Skoog concluded that Dupuytren's contracture begins when the fibers of the palmar aponeurosis are ruptured. The ruptured fibers then heal by proliferation of fibrous tissue. The proliferating tissue gradually undergoes all the stages of maturation of connective tissue until a mature, contracted, scarlike stage is reached. The iron pigment was said to represent minute hemorrhages which occurred at the time of the rupture of the fibers.

Warren in 1953 reported the examination of seventy-seven specimens of hands affected with Dupuytren's contracture. He noted chronic inflammatory cells in forty-four but not in thirty-three specimens. Inflammatory cells had perivascular distribution in forty-two of the forty-four specimens in which they were present. Warren suggested that the chronic inflammatory cells were the result and not the cause of fibroplastic proliferation. New actively growing vessels were noted. The distribution of proliferating fibrous tissues suggested proliferation at the periphery to Warren. He concluded: "the conception of this lesion as a benign neoplasm of palmar fascia best explains the clinical and pathological processes."

From the survey of the literature it can be seen that there are four major concepts concerning the histopathology of Dupuytren's contracture: (1) benign hyperplasia of fibrous tissue arising in the palmar aponeurosis; (2) inflammatory changes arising in the interstitial connective tissue of the palm and secondarily involving the aponeurosis; (3) benign neoplasm—fibroma; and (4) cellular hyperplasia in response to rupture of the collagenous fibers of the palmar aponeurosis.

MATERIAL

Specimens from sixty-one of our patients were available for examination. We were unable to correlate the degree of involvement of the palmar fascia or the maturity of the hyperplastic fibrous tissue with the age, sex, or occupation of the patient.

Histopathology

When the mature contracted bands of tissue are examined, one sees a mass of dense collagenous tissue. The fibers are quite thick and closely packed in parallel bundles. The individual fibers are straight as if under tension. The nuclei are elongated and lie compressed between the collagenous fibers. They are between ten and twenty times as long as they are wide. They stain so intensely with the nuclear stains that no nuclear detail can be seen. The over-all appearance is not unlike that of the normal aponeurosis except for a decrease in number of nuclei (Fig. 1). We have interpreted this stage, as have others, as the mature contracted stage of the disease. Regardless of the pathogenesis of the disease, this is the final stage. We were not able to demonstrate any areas of mature collagenous fibers either in the uninvolved aponeurosis or in the mature contracted bands, where we thought the appearance suggested rupture of the fibers.

When attention is turned to the more cellular areas of the diseased fascia, proliferation of fibrous tissue is seen. In those areas which we have interpreted as the most recent areas of proliferation, the nuclei are large and oval in shape, approximately two to three times as long as they are broad. The nuclear membrane is distinct and the nuclei are pale. A nucleolus is easily visible, stained somewhat more intensely than the remainder of the nucleus, which is finely granulated. Occasionally fine darker strands of material are visible within the nucleus. Mitotic figures are rare even in the most actively proliferating areas (Figs. 2 and 3).

The cellular margins are indistinct and cannot be identified. Between the large, plump nuclei there is a fibrillar network, made up of very fine fibrils arranged in a haphazard fashion. In hematoxylin and eosin preparations this fibrillar network stains light lavender. This type of cellular growth may be found arising in several different foci within one section and in different places in the palmar fascia.

The actively proliferating tissue has, in many areas, a nodular arrangement. Skoog interpreted these small actively proliferating nodules as the earliest stage of the disease. Warren noted that some of these early nodules appear to be proliferating at the periphery. We did observe this in some instances, but not with enough regularity to say that such a pattern was consistent. The tissue at the periphery of the nodules of proliferating tissue blends into the surrounding more mature fibrous tissue without any sharp demarcation

(Fig. 4). There is no suggestion of capsule formation around any of these proliferating areas. At times small elongated projections of the proliferating tissue appear to be arising from the nodule and pushing out into the mature collagenous fibers.

In nine of our sixty-one specimens we observed iron pigment in the center of hypercellular areas (Figs. 5 through 8). In hematoxylin and eosin preparations this pigment is golden brown and finely granular. It may lie in the intercellular spaces or within cells which appear to be phagocytic. This pigment stains positively for iron with Prussian blue. As far as we can determine this was not described before Skoog reported the presence of iron pigment in his 1948 monograph. We have not been able to find any subsequent reports of iron pigment in the hypercellular areas of tissue affected by Dupuytren's contracture.

Perhaps iron pigment has not been reported more frequently because it is difficult to find. A careful search of actively proliferating areas at a magnification of 400 diameters

FIG. 1

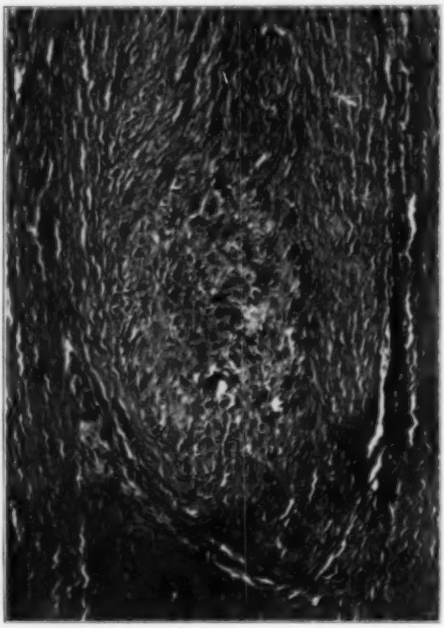

FIG. 2

Fig. 1: Photomicrograph of a longitudinal section made through a band of mature fibrous tissue (hematoxylin and eosin, × 90).

Fig. 2: Photomicrograph (× 135) showing a nodule of actively proliferating fibrous tissue. This is the earliest stage of Dupuytren's contracture.

or more is necessary. At lower powers the pigment is easily passed over. Iron pigment is observed only in the nodules of actively proliferating tissue. Perhaps no more than nine of the sixty-one specimens were observed to have iron pigment because not all specimens contained the proliferating tissue. It must be noted, however, that many nodules are to be seen which do not have iron pigment. Presumably it is not found in the more mature stages of the disease because it was removed by phagocytes. Iron-pigment deposits were observed neither in the mature contracted scar nor in the normal aponeurosis.

We were unable to demonstrate rupture of aponeurotic fibers at the site of fibrous-tissue proliferation. Observations after preparation with Masson connective-tissue stain suggested rather that the collagenous fibers of the aponeurosis were pushed aside by

masses of proliferating fibroblasts (Fig. 9). The fibrils about the immature fibroblasts are very fine. As the nodules undergo maturation into more mature fibrous tissue the fibrils become more dense and thickened. The fibrils of the proliferating nodules blend without sharp demarcation into the mature collagenous tissue. Study of tissue prepared with Verhoeff's elastic-tissue stain indicated that the new fibrils are not elastic tissue (Fig. 10).

Associated with the areas of proliferating tissue there is an increase in vascularity. Numerous areas of actively growing capillaries are noted.The capillaries are present both within and at the periphery of the nodules of proliferating tissue (Fig. 11). At the periphery of the nodules one often observes numerous thick-walled blood vessels which are much larger than the capillaries. The nuclei are round or oval rather than flattened and elongated, as is usually seen in endothelium. A great deal of nuclear detail is visible and cellular margins are more distinct. Frequently surrounding these vessels are one or more layers of concentrically arranged cells with oval or round nuclei. These vessels cannot be con-

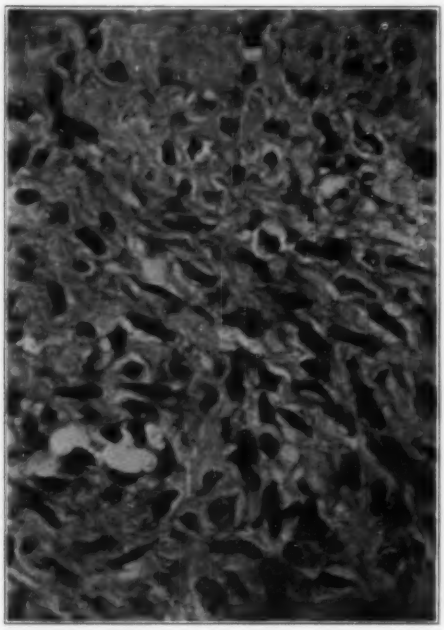

FIG. 3

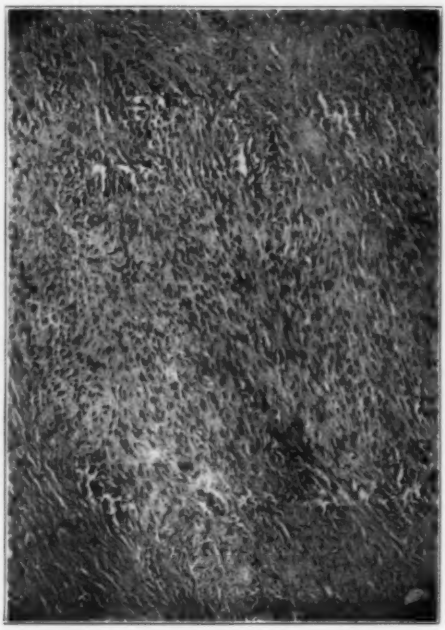

FIG. 4

Fig. 3: Photomicrograph of actively proliferating fibrous tissue. These areas are interpreted as the early lesions of Dupuytren's contracture (hematoxylin and eosin, × 400).

Fig. 4: Photomicrograph shows that proliferating fibrous tissue blends imperceptibly into the more mature fibrous tissue. Note the absence of capsule formation (hematoxylin and eosin, × 90).

sidered peculiar to the disease since they are noted in the normal aponeurosis (Fig. 12). We have the impression that they are increased in number in tissue affected by Dupuytren's contracture, but cannot demonstrate this conclusively.

Often at one point in the wall of such a vessel there may be a great increase in cellularity. These areas blend insensibly into the proliferating fibrous tissue of the lesion. These changes are apparently quite similar to those which were originally described by Langhans. There is no inflammation around the small vessels (Figs. 13 and 14).

Perivascular collections of inflammatory cells were observed in sixteen of the sixty-one specimens. The inflamed vessels are usually in the fatty or interstitial tissue around the palmar fascia (Fig. 15); an inflamed vessel within the aponeurosis itself was observed

once (Fig. 16). While we removed as little fat as possible in excising the palmar fascia, there was some fat present on all specimens. The inflammatory cells around the vessels were usually small lymphocytes. Occasionally the typical nucleus of a monocyte was observed.

As previously mentioned, the proliferating fibrous tissue blends, without sharp demarcation, into the surrounding mature fibrous tissue. It is possible to trace the evolution of the young growing tissue into mature dense collagenous tissue. The nuclei elongate and stain more deeply and the nuclear detail becomes obscured. The staining of the intercellular fibrillar network changes from lavender to the red orange usually associated with eosin-staining of collagenous tissue. The fibrils begin to assume a more regular distribution and finally become closely packed parallel mature collagenous-tissue fibers. At the same time the haphazard arrangement of the nuclei changes. They become arranged in sheets with their long axes oriented more or less in the same direction.

FIG. 5

FIG. 6

Fig. 5: Same nodule as shown in Fig. 2. The fine black granules (*A*) are iron pigment stained blue. Note how easily this would be overlooked at ordinary magnifications, particularly if the nuclei were stained (Prussian blue, eosin counterstain, × 135).

Fig. 6: Same nodule as that in Fig. 5 (Prussian blue, eosin counterstain, × 600).

As maturation progresses the vascularity decreases. In more mature nodules the abundant capillaries cannot be identified. As the mature collagen-tissue stage is reached, the increase in vascularity is no longer present.

Pathogenesis

Perivascular accumulation of chronic inflammatory cells was noted in only sixteen of sixty-one specimens. Meyerding [39] observed this in twenty-four specimens from fifty-seven patients. Warren observed it in forty-four of seventy-seven specimens. The perivascular inflammation was noted to be in the fatty and interstitial tissue of the palm. Inflammatory cells were found about a vessel in the palmar fascia only once. In no instance

were the inflammatory cells observed around the vessels within or near the actively proliferating tissue. These observations lead us to conclude that perivascular inflammation is a result of fibrous-tissue proliferation within the palmar aponeurosis and not the cause of the proliferation. The inflammation may be a direct result of the proliferation or it may be present because the contracted areas of the palm are subjected to increased irritation.

The question naturally arises: why consider only nine instances of iron-pigment deposits as significant while discounting the importance of sixteen instances of perivascular inflammation? The perivascular inflammation is observed to lie outside the aponeurosis. In no instance were vessels near or within areas of proliferating tissue inflamed. On the other hand, iron-pigment deposits were found only in the earliest lesions of the contracture. It seems, therefore, that iron-pigment deposition is more closely associated with the early lesions of Dupuytren's contracture than is perivascular inflammation.

(The term *early* as used here refers to the stage of maturation of the fibrous tissue in

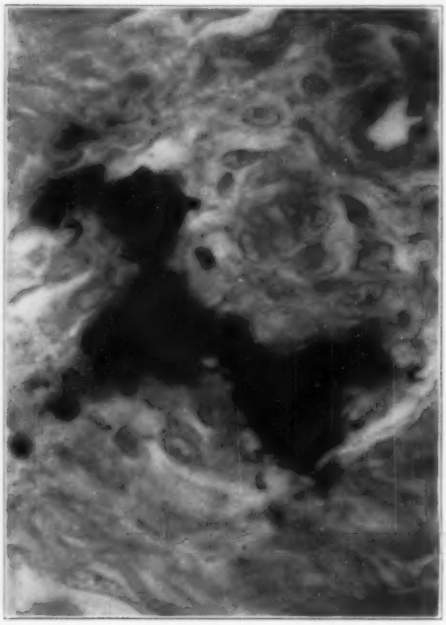

FIG. 7

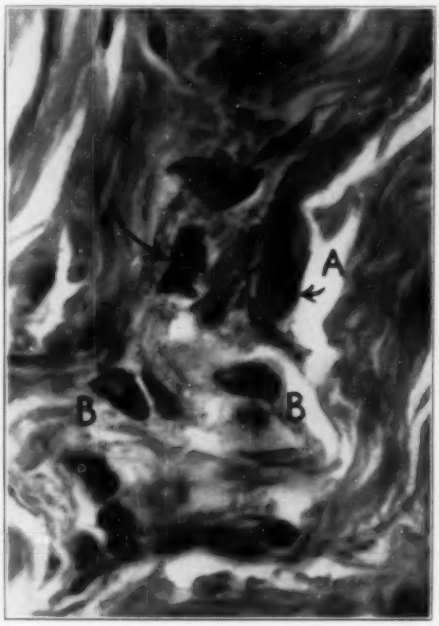

FIG. 8

Fig. 7: Young nodule of fibrous tissue with pronounced iron-pigment deposits are shown in photomicrograph. These deposits appear blue in the stained section (Prussian blue, eosin counterstain, × 800).

Fig. 8: Photomicrograph showing very early fibrous-tissue proliferation. The material (*A*) is blue in the section and represents iron pigment, while the young nuclei (*B*) are purple (Prussian blue, hematoxylin and eosin counterstain, × 1100).

the specimen and has nothing to do with the chronological history of the patient's disease. At times immature nodules of fibrous tissue containing iron pigment are found in the palmar fascia of patients who have had the contracture for several years. Other patients who have the iron pigment and the immature nodules had the contracture for only a few months. This probably means that in those patients in whom proliferating tissue containing iron pigment was found we had interrupted the contracture during one of its active proliferating phases, while in those patients in whom this type of tissue was not found, the contracture was relatively quiescent when operated upon.)

Skoog does not record the number of times he observed iron pigment in the twenty-nine specimens he examined. An incidence of only nine positive observations in sixty-one

specimens is insufficient evidence on which to base a pathogenic or etiological theory. It is not clear whether the iron pigment is associated with the cause of the lesion or is a result of the presence of the lesion. The presence of the iron pigment certainly suggests old hemorrhage associated with the actively proliferating fibrous tissue. Evidence of hemorrhage causes one to consider trauma as the cause of the hemorrhage. We are unable at this stage of our studies to formulate a pathogenic theory which either includes or excludes trauma. We do feel, however, that the subject is by no means a closed issue. Clearly, more work is necessary in this field.

The proliferating areas appeared to be invading the mature collagenous tissue without encapsulation. The similarity between the microscopic appearance of Dupuytren's contracture and fibrosarcoma has often been noted, but metastasis has never been reported. Certainly this is not a malignant fibrous-tissue neoplasm. If Dupuytren's contracture be a benign fibrous-tissue neoplasm, it is a most unusual one. Moore wrote, "the fibroma is a

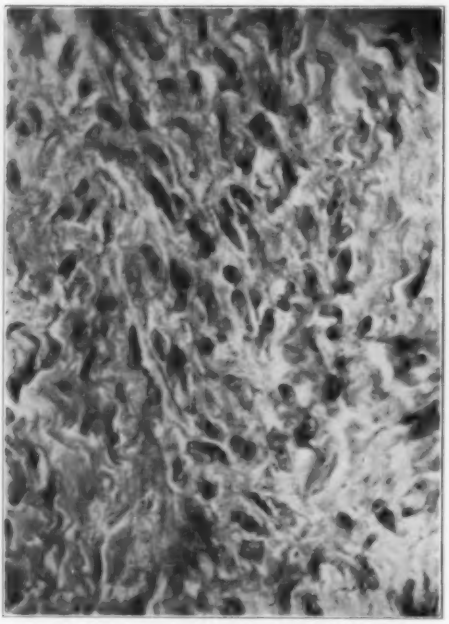

FIG. 9

FIG. 10

Fig. 9: Note that in this photomicrograph the nodule of proliferating tissue appears to displace mature fibers. There is no suggestion of rupture of mature fibers (Masson connective-tissue stain, Gomori's trichrome counterstain, × 135).

Fig. 10: Photomicrograph of control material containing elastic tissue shows dense black elastic-tissue fibers with this stain. Note that in this specimen from a patient with Dupuytren's contracture there is no new formation of elastic tissue (Verhoeff's elastic-tissue stain, × 135).

circumscribed, encapsulated, usually lobulated tumor. . . ." No suggestion of encapsulation has been found in our specimens, nor have we found any reported in the literature. In addition, several areas of proliferating fibrous tissue are observed within one hand, and even within the same section. This implies a more or less simultaneous multicentric origin. Because of the lack of encapsulation, the multicentric origin of the proliferating tissue, and the diffuse distribution of the disease, we do not think that this is a benign neoplasm in the ordinary sense of the term.

We did observe large pacinian corpuscles in our specimens, but were unable, on anatomical grounds, to attach pathogenic importance to them.

We have concluded that the pathological changes in Dupuytren's contracture should be described as follows: there is an active proliferation of young fibroblasts in intimate association with numerous thick-walled vessels. There is an increased capillary vascularity. The proliferating tissue forms non-encapsulated nodules of varying size within the aponeurosis. Perivascular inflammation of vessels in the fatty and interstitial tissue around the aponeurosis occurs frequently. These nodules of tissue gradually undergo all of the well known changes from young, cellular, immature fibrous tissue into mature, contracted, dense, collagenous tissue. As the maturation progresses, the vascularity decreases. The cause of these changes is unknown, but does not appear to us to be inflammation or neoplasia. The process can best be described as fibroplasia or fibromatosis of unknown etiology. The significance of iron pigment in actively proliferating nodules needs further investigation.

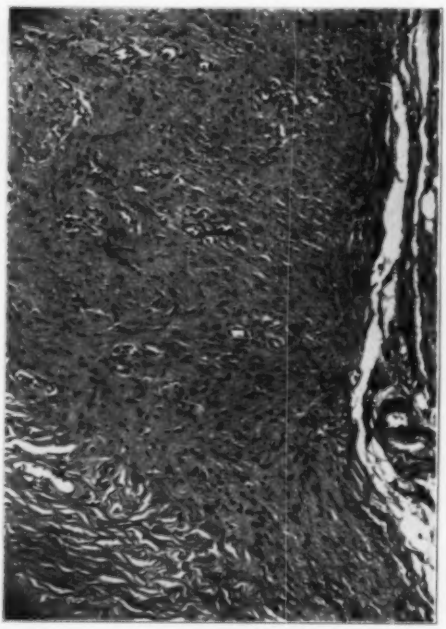

FIG. 11

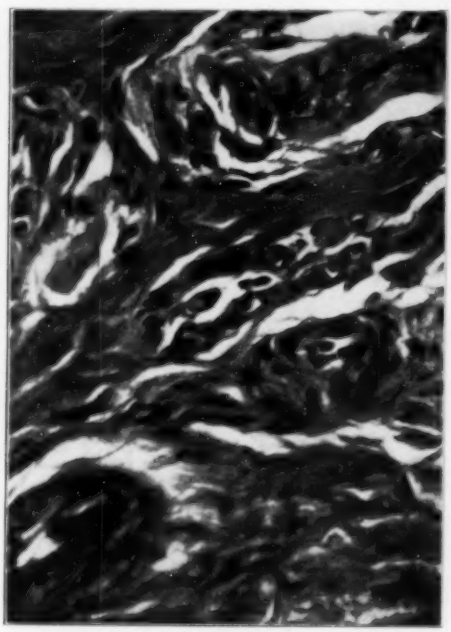

FIG. 12

Fig. 11: Photomicrograph of area of proliferating tissue affected with Dupuytren's contracture. Note marked vascularity within and at periphery of the nodule (hematoxylin and eosin, × 90).

Fig. 12: Photomicrograph showing thick-walled vessels in the palmar fascia. These vessels are seen both in normal fascia and near the periphery of proliferating nodules (hematoxylin and eosin, × 400).

TREATMENT

Non-operative Treatment

To discuss non-operative treatment of Dupuytren's contracture with local injections of pepsin [22], fat solutions [50], fibrolysin [36], copper sulphate [23], and pancreatic extract [47] would serve no useful purpose. The weight of responsible opinion now holds these methods to be without value. Cortisone was also found to have no effect upon the disease [3].

Treatment with oral tocopherol has been reported to improve Dupuytren's contracture [51, 52]. We have had an opportunity to observe the effect of alpha-tocopherol, 300 milligrams daily for three weeks, followed by 100 milligrams daily for several weeks, on three patients. We felt that there was a temporary softening of the contracture, but the

progressive course of the disease was not altered. Two of these patients subsequently had surgery.

Hydrocortisone acetate has been injected into the palm by Zachariae and Zachariae. They noted a temporary softening of the contracture in early cases, but did not believe that hydrocortisone would halt the progression of the disease. Howard, Pratt, and Bunnell injected hydrocortisone in the wound at the time of closure after operation for Dupuytren's contracture. Their patients had almost no postoperative pain. We have had no experience with hydrocortisone in either the non-operative or postoperative treatment of Dupuytren's contracture.

Radiation therapy has been used in the treatment of Dupuytren's contracture. Finney[17,18] treated fifty-nine patients with roentgen therapy. Twenty-five were treated with gamma radiation and thirty-four with medium-voltage x-ray. He noted a lessening of the feeling of tightness of the palm within one and a half months. Maximum improvement in function usually occurred within six months. Of twenty-five patients treated with radium, fifteen showed a good functional result. Only eighteen patients treated with x-ray were evaluated; eight of these had a good functional result. Finney suggested a combination of preoperative irradiation and surgery for more advanced cases. We have had no experience with radiation in Dupuytren's contracture, but feel that the percentage of cases which showed a good functional result in Finney's series is less than might be expected from proper surgical treatment.

FIG. 13

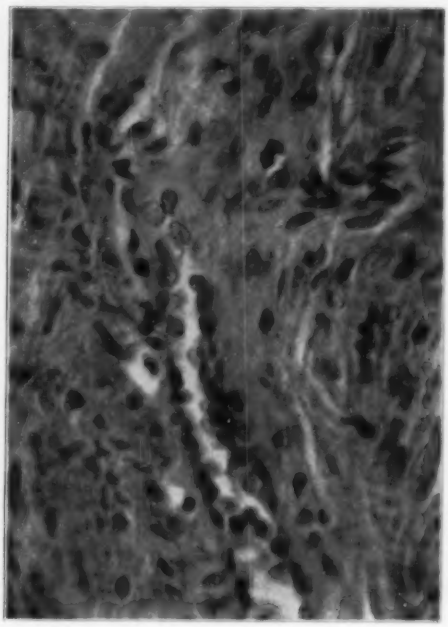

FIG. 14

Fig. 13: Photomicrograph of a thick-walled vessel with perivascular tissue blending into the proliferating nodule (hematoxylin and eosin, × 400).

Fig. 14: Photomicrograph of a longitudinally cut vessel. Note how the proliferating tissue of the lesion appears to arise from the perivascular tissues (hematoxylin and eosin, × 400).

Surgical Treatment

The majority of those most experienced in the care of this condition agree that the

most effective treatment is surgical[5, 8, 11, 49]. There are three generally recognized types of operation for this disease. There often exists some question, however, about what type of operation should be performed in a given case. Fasciotomy, or simple division of the contracted bands, is the simplest operative procedure; it is done upon the contracted bands under direct vision or blindly with a cataract knife. Excision of the diseased fascia with varying margins of uninvolved fascia is the next simplest procedure, a limited or partial fasciectomy. Finally, there is a more radical operation in which all recognizable palmar fascia, together with the vertical septa which pass to the pre-osseous fascia and the pretendinous bands extending into the fingers is excised.

In our series, seventy-four of the ninety-nine patients (eighty-nine hands) were operated upon. The youngest patient operated upon was twelve years old, the oldest, seventy-eight. The average duration of the symptoms before surgery was 4.6 years.

Surgery is by no means indicated in all cases of Dupuytren's contracture. There is

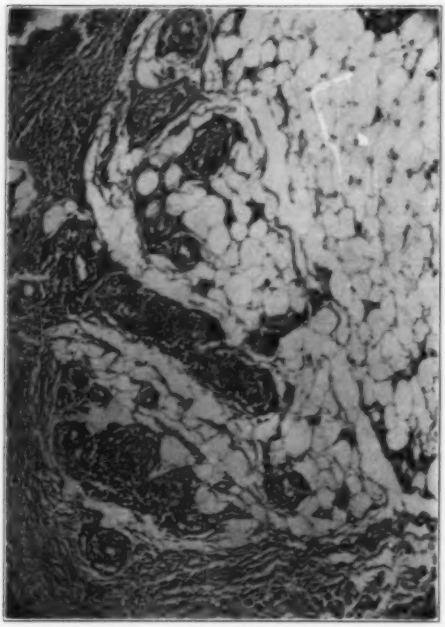

FIG. 15

FIG. 16

Fig. 15: Photomicrograph showing perivascular inflammation in the fat near the palmar fascia. The inflammatory cells are predominately lymphocytes (hematoxylin and eosin, × 90).

Fig. 16: Photomicrograph showing perivascular inflammation within the palmar fascia. This finding is uncommon (hematoxylin and eosin, × 400).

no doubt that many patients with established contractures of moderate to severe degree require surgical relief. This is particularly true when the contracture is interfering with the patient's ability to carry on with his occupation. When to operate and whether or not to operate on a patient with the earlier stages of the disease pose a more difficult problem. Probably many patients never seek formal medical advice about their Dupuytren's contracture, getting along perfectly well without any treatment.

It is not possible to forecast accurately the progression or rate of progression of the contracture in any one patient. One would not like to operate upon a patient with mild contracture if it were certain that the disease would remain stationary at that point. On the other hand the operation is technically easier and the results are better when the

contracture is in a relatively early stage. When the contracture has existed so long that there are permanent joint changes, a perfect result is difficult to obtain. When it is not certain that an operation is indicated, observation of the patient for a few months is helpful. If the contracture is progressing rapidly operation is then recommended. If it remains stationary, and the contracture is in the earlier stages, surgery is not required.

From a review of the literature and our own experience we have concluded that the operation must be fitted to the individual patient. Factors which must be considered in determining the type of operation include age, general physical condition, associated diseases, occupation, stage of the disease, and the type of hand. A hand with marked arthritic changes does not stand extensive surgery well, as does not a thick broad hand with stubby fingers and some degree of stiffness, often seen in laborers. The choice of operation must also be influenced by the tendency of the contracture to recur if an inadequate excision be performed. Four of the patients in our series were operated upon for a recurrence of the disease after an operation done elsewhere.

Fasciotomy has been advocated as a preliminary operation in severe cases in preparation for more radical procedures (Figs. 17-A, 17-B, and 17-C). The preliminary operation allows stretching of the skin as well as gradual readjustment in other tissues and an opportunity to gain increased joint extension before the definitive operation. We have carried out preliminary fasciotomy three times. Two of these patients have returned for further surgery and the contracture is progressing in the third patient. Fasciotomy as the sole treatment of the disease is limited to those patients in whom more extensive procedures are contra-indicated. This includes the very elderly and those patients who have an associated disease which prevents extensive surgery. Fasciotomy is practicable in such patients only if the disease be manifested by prominent contracted longitudinal bands. We have used fasciotomy as the definitive operation twice, once in a man seventy-eight years old, and once in a man sixty-four years old, in whom radical fasciectomy on the other hand was done at the same time.

We have not performed blind or subcutaneous fasciotomy since we feared injury to the digital nerves in the palm. Bunnell and Boyes have performed subcutaneous fasciotomy in the palm, but caution that it is a dangerous procedure in the fingers.

Partial fasciectomy was practiced by Kocher in the latter part of the nineteenth century. Recently interest in this operation has been revived, particularly by Conway and Hamlin. Skin slough is a feared complication in all operations for Dupuytren's contracture. There is less chance of producing avascular skin flaps in a partial excision of the aponeurosis than there is in a total excision of that structure. Hamlin was impressed by the decreased postoperative morbidity when the limited operation was performed. Some patients, however, had postoperative stiffness in our series. The difficulty here is inability to flex the fingers rather than loss of extension. Stiffness may involve fingers which were not originally involved in the contracture. Postoperative stiffness was our most frequent complication of surgery. Usually the patients were able to work this out with the help of exercise and physical therapy although in some it persisted.

Partial fasciectomy, excision of the obviously contracted fascia with a narrow margin of normal fibrous tissue around the contracture, was performed by us on twenty hands. In six hands this was done through a sinuous longitudinal incision in the palm. Usually these patients had one prominent longitudinal band of contracted fascia and the rest of the palm was free of the disease. Two of these twenty patients who had partial fasciectomy had poor results: one due to prolonged stiffness and the other to persistent flexion deformity of the finger. One had a good result limited by slight flexion deformity of one finger. The remaining seventeen had excellent results. We have seen no recurrence in these patients, although several of them have not been followed long enough to preclude the possibility of recurrence.

Radical or total excision of the palmar fascia was employed in sixty-four patients;

FIG. 17-A

FIG. 17-B

Fig. 17-A: Preoperative photograph of the hand of a housewife forty-eight years old with severe Dupuytren's contracture.

Fig. 17-B: Photograph shows patient's ability to extend fingers after preliminary fasciotomy; definitive fasciectomy is pending.

Fig. 17-C: Artist's sketch of fasciotomy.

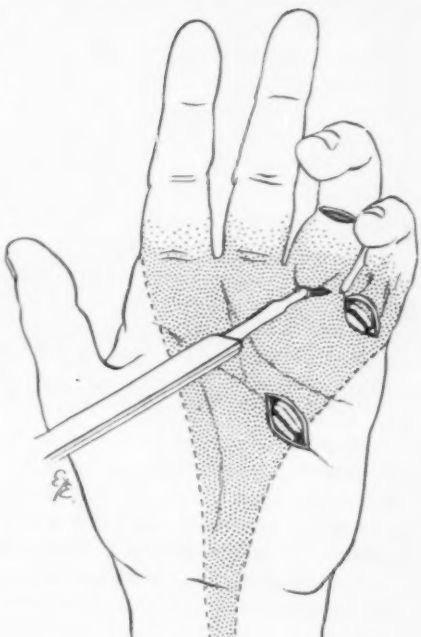

FIG. 17-C

partial fasciectomy, in twenty; definitive fasciotomy, in two; and preliminary fasciotomy, in three. In two patients excision of a finger nodule only was done. In eight patients skin-grafting of the wound was necessary because the contracture had irreparably damaged the overlying skin. Contracted bands and nodules of diseased fascia in the fingers were removed through appropriate incisions. A mid-lateral incision was used in sixteen instances; transverse incision in the finger creases, in twelve instances; L-flap incision, in ten; oblique incision, in five; Z incision (McIndoe), in three; and a bayonet incision, in one.

The palmar incisions employed in these operations included six sinuous longitudinal incisions and four L-flap incisions. Twenty-eight had a combined transverse incision in the distal palmar crease and oblique incision in the thenar crease; forty-nine had a single transverse incision in the distal palmar crease; and two had no palmar incision.

General anaesthesia was used during the operation unless it was contra-indicated. We found that brachial block anaesthesia tends to wear off before the operation is concluded. In addition, brachial block anaesthesia, while rendering the hand painless, fre-

quently does not relieve the pain produced by the tourniquet. The operation was always performed in a bloodless field, secured by a wide pneumatic tourniquet inflated to a pressure of 280 to 300 millimeters of mercury. The finger incisions were varied to meet the needs of the individual situation.

Small transverse incisions in the flexion creases of the fingers may be used for fasciotomy and also for excision of small discrete nodules on the anterior surface of the finger. Usually a more adequate exposure in the finger is needed. An oblique incision beginning in the mid-lateral line at the proximal interphalangeal joint and passing obliquely across the proximal phalanx will give good exposure. The proximal portion of this incision must not cross the finger web, as pointed out by Mason [37].

Mid-lateral incisions on the side of the finger give adequate exposure if the contracture is limited to one side of the finger. Flaps may be elevated, if necessary, by incising the skin of the flexion crease over the proximal interphalangeal joint. We have had limited experience with the Z incision described by Skoog and attributed to McIndoe, but we have found it satisfactory.

The sinuous longitudinal incision in the palm can be used only for partial fasciectomy. This incision is centered over the contracted longitudinal band. Transverse incisions are indicated for more complete excision of the fascia. A simple long transverse incision in the distal portion of the palm will give adequate exposure in most cases. If needed, a curved incision may also be made in the thenar crease. A bridge of subcutaneous fat and skin is then elevated between the transverse and thenar-crease incisions. The bridge of skin must not be too narrow or it will not have an adequate blood supply.

In elevating the skin flaps, careful sharp dissection with frequently changed knife blades is employed. All of the subcutaneous fat is elevated with the skin. Mason [29] pointed out the importance of preserving the small vessels which penetrate the fascia from below and supply the skin; we have paid close attention to this detail. After the subcutaneous fat is dissected away from the palmar fascia as far distally and proximally as possible, the fascia is divided transversely in the proximal portion of the palm. We did not think it necessary to reach the insertion of the palmaris longus, since the most proximal portion of the fascia is rarely involved in the disease.

The fascia is then dissected away from the deep structures of the palm. Kanavel, Koch, and Mason have emphasized the vertical septa which pass from the palmar to the pre-osseous fascia (Fig. 19). These septa pass between each flexor-tendon sheath and neurovascular bundle. They are frequently involved in the contracture and should be excised. They are excised as deeply in the palm as possible. Nerves may be surrounded or dislocated by masses of diseased fascia in these regions; consequently careful identification and retraction of each digital nerve is necessary in order to avoid injuring them.

After the dissection is complete, the tourniquet is released and all bleeding vessels are ligated. Absolute hemostasis in the palm and fingers is essential. The tourniquet is then reinflated. If the hand is elevated for a minute or two before the tourniquet is inflated most of the blood will drain out of the hand and forearm. If the bloodless field is then maintained until the wound has been closed and a compression dressing has been applied, there is less chance of wound hematoma. This is particularly important when a skin graft has been applied in the wound closure. The wounds are closed with fine monofilament-nylon suture. Small rubber tissue drains are placed in the wounds. A large compression dressing is held firmly over the wound by sutures as advocated by Tanzer and by Mason [37]. A voluminous compression dressing then covers the entire hand and forearm. An aluminum or plaster splint which holds the hand in position of function is incorporated into the dressing. The tourniquet is not released until the entire compression dressing and splint have been applied.

In eight of our cases so much palmar skin was irreparably damaged by the contracture and was excised that primary closure of the wound was not possible. Conway [12] found

FIG. 18-A

FIG. 18-B

Fig. 18-A: Preoperative photograph of the hand of a male office worker, seventy-eight years old.

Fig. 18-B: Photograph shows patient's ability to flex hand following definitive fasciotomy.

Fig. 18-C: Patient's ability to extend hand.

FIG. 18-C

thick split-thickness free grafts to be usually satisfactory. We have used grafts which we consider almost full thickness (.022 to .025 inch) taken from the thigh with an electric dermatome. These donor sites do not heal readily; consequently they are covered with thin split grafts taken in the same way from an adjacent area. We have not had occasion to use the method of dorsal-flap grafting described by Bruner.

In the postoperative period the hand is maintained in elevation either on pillows when the patient is in bed, or in a sling tied with the hand quite high on the chest when the patient is ambulatory. The large gauze dressing sutured over the palm may be removed on about the fourth day for removal of drains. Skin sutures are not removed in less than ten days. The hand is held immobile in the position of function until all of the wounds are completely healed. Following that, daily warm handbaths are started and the patient is encouraged to begin moving the hand. Gradually increasing exercise is instituted. Most patients are allowed to return to work in about four weeks.

RESULTS

Eighty-nine hands were operated upon in seventy-four patients. All of the operations were performed between 1949 and 1956. The longest follow-up in the series is seven years. The shortest follow-up is six months, excepting three patients who are regarded as operated upon too recently to evaluate and two patients who were lost to follow-up. The mean length of time which these patients were followed is 3.2 years; we have seen no recurrence

in this series. The length of time that the patients have been followed is too short to preclude the possibility of recurrence.

In evaluating the results of surgery one must consider the postoperative function of the hand, the duration of postoperative disability, and the ability of the patient to perform his usual work. We classed fifty-two hands as having an *excellent* result; extension returned to normal or nearly normal, there was no limitation of flexion, and the hand was free of pain. Twenty-two hands had a result classified as *good;* most of these were not in the excellent group because of slight residual stiffness. These patients were able to extend the fingers well, to carry on their usual work, were free of pain, but had slight persistent limitation of the last few degrees of finger flexion. Troublesome postoperative stiffness is encountered particularly in the following types of individuals: the elderly, those who have arthritis with restricted joint flexion preoperatively, and the laborer who has developed a thick, broad, stiff hand. These types of hands apparently do not stand trauma, including surgical trauma, well. This observation led us to employ more conservative operations in persons who have these types of hands. Five hands had *fair* results and five had *poor* results. Operative complications such as delayed healing in four hands; hematoma of the palm, in two; flexion contracture of the finger in four; and infection in one, contributed to these poor results. The only wound infection occurred in the patient with diabetes.

FIG. 19

Drawing shows complete excision of palmar fascia through incisions in the distal palmar and thenar creases. Note vertical septa passing from palmar to pre-osseous fascia, separating tendons and neurovascular bundles.

CONCLUSIONS

Dupuytren's contracture, 126 years after it was described by Dupuytren, remains a disease of unknown etiology. On the basis of histological studies of specimens from sixty-one patients, we conclude that Dupuytren's contracture is a fibrous-tissue proliferation arising within the palmar fascia in intimate association with thick-walled vessels together with an increase in capillary vascularity. This tissue undergoes the well known stages of maturation of fibrous tissue until a firm, relatively avascular, contracted scar is formed. The pathological changes do not suggest to us that the lesion is due to trauma, inflammation, or neoplasm. Further study is needed to determine the significance of iron pigment in the early lesions. Surgery is the only form of treatment which will produce any lasting benefit in this disease, although administration of tocopherol and irradiation may produce some temporary improvement. The operation must be fitted to the individual patient. Complete excision of the palmar fascia is indicated in most cases; however, partial excision of the fascia and fasciotomy have their place in selected cases. With proper choice of operation and careful attention to operative details excellent or good results can be expected in between 80 and 90 per cent of patients operated upon.

NOTE: We are indebted to Dr. Michael L. Mason, Chicago, Illinois, for allowing us to use his very fine file of articles on Dupuytren's contracture.

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DISCUSSION

Dr. Sumner L. Koch, Chicago, Illinois: The occasional presence of iron pigment is interesting, but may have a very simple explanation. Localized trauma with tearing of fibrous tissue and capillary hemorrhage must be a rather common occurrence in patients with firmly flexed fingers, and it is difficult to see how the presence of such pigment can serve to explain the cause of the fibrous-tissue formation.

In our experience Z-shaped incisions cannot often be successfully employed on the thickened and contracted palmar skin so often present. We have come more and more to use whole-thickness grafts to cover what often becomes a considerable defect when wide excision of fibrous tissue permits contracted fingers to extend. The important principle of compression in the treatment of wounds—surgical or accidental—needs constant re-emphasis. I believe that, along with careful cleansing, arrest of bleeding, and accurate surgical repair, it is the essential element in success.

Dr. Julian M. Bruner, Des Moines, Iowa: In this very interesting paper, Dr. Larsen has touched upon an important fact, not previously emphasized, that in patients with Dupuytren's contracture stiffness of the hand after radical fasciectomy is apt to develop. This may occur after other radical surgery on the hand in patients of the same age group, but we have the impression that it is more common in hands affected by Dupuytren's disease. It is usually temporary but may persist, and if so, it is disabling.

Until we have some way of predicting or controlling this undesirable sequela, it may be said that radical fasciectomy, if routinely applied to all hands with Dupuytren's contracture, carries a known risk. In the authors' series twenty of seventy-four patients had trouble with postoperative stiffness of the hand. There-

(*Continued on page 832*)

Surgical Treatment of Trigger-Finger By a Subcutaneous Method

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Trigger-finger is a condition characterized by inability to flex and extend the finger evenly. This is due to an interference in the mobilization mechanism of the finger. The unevenness of action may be likened to the motion of a spring, and is due to the presence of an enlargement in the tendon in front of the opening of the proximal annular ligament or osteofibrous canal of the finger.

When the affected finger is moved from flexion to extension, the enlargement is caught in the osteofibrous canal and, because of resistance, causes on release, pain and a springing effect. The nodule can be large enough to fix permanently the finger in flexion

FIG. 1

FIG. 2

Fig. 1: Drawing showing the osteofibrous canals in the hand. The transverse fibers correspond to the pulleys. The nerves and arteries are on either side of the canals.

Fig. 2: Roentgenogram of the hand showing the palmar creases and the interdigital spaces. The origins of the fibrous canals of the fifth, fourth, and third digits are at the level of the distal palmar crease, while the origin of the fibrous canal of the second digit is at the level of the proximal palmar crease. This is more distal than examination of the skin indicates.

(camptodactylia). Although the origin of these lesions can be attributed to a single sizeable trauma or to repeated microtraumata, many cases are without any precise etiology.

On clinical examination, the enlargement of the tendon is found just under the metacarpophalangeal articulation. An interphalangeal swelling is, as yet, unknown. The enlargement is usually painful under pressure, and during movement of the finger, its motion can be felt under the skin. Often, the springing seems to take place at the level of the distal interphalangeal articulation, the most difficult to place in extension. When surgery is performed at this level, the real cause is found to be situated in a more proximal location.

FIG. 3

FIG. 4

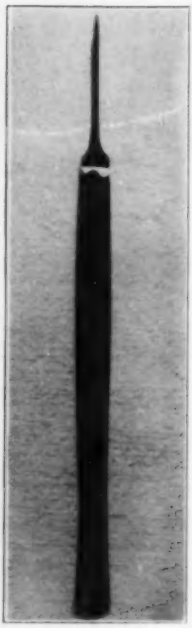

FIG. 5

Fig. 3: The opening of the osteofibrous canal of the thumb is at the level of the proximal palmar crease when the hand is held in the anatomical position.

Fig. 4: The relationship between the palmar creases and the ends of the osteofibrous canals is shown.

Anatomicopathologically, the presence of a small fibrinous nodule or cyst can be seen in the flexor tendon. The lesion appears more often in the thumb than in the fingers. Some of these nodules can disappear spontaneously and others respond well to physical therapy. Many require surgical intervention. A sesamoid bone under the tendon rarely is the cause of this condition.

Anatomy of the Osteofibrous Sheaths

Along the level of the digits, the flexor tendons lie within the synovial sheaths and osteofibrous canals which hold these tendons fixed against the palmar surface of the phalanges. This canal, or pulley, is composed of transverse and interwoven fibers spreading out from the distal insertion of the tendon in the phalanx, up to about two centimeters proximal to the metacarpophalangeal articulation. The so-called pulley is a reinforcement of the canal by transverse fibers at the level of the proximal and middle phalanges and these extend to the proximal end of the head of the corresponding metacarpal.

From the topographical point of view, the common volar digital vessels and nerves pass along both sides of the flexor tendons on the distal part of the palm and divide at the level of the metacarpal heads into the collateral nerves and arteries of the fingers. In this way, no vessels or nerves lie between the osteofibrous canal and the skin (Figs. 1 to 3).

Skin Markings

The metacarpophalangeal articulations are situated for the last three digits two centimeters distal to the proximal palmar crease and for the index finger and thumb one centimeter distal to the proximal palmar crease (Fig. 4). The proximal extremity of the osteofibrous canal ends about one centimeter proximal to the metacarpophalangeal articulation, and its origin is located at the level of the distal crease for the last three digits,

and at the level of the proximal crease for the thumb and index finger. The openings of the osteofibrous canals should, therefore, be at the crossing of the palmar creases with a mid-line running along the palmar surface of the fingers.

Method

The instrument used to correct trigger-finger is a fine tenotome with a blade one millimeter wide and one centimeter long; a fine sharp-pointed scalpel can also be used (Fig. 5).

The skin should be disinfected with cetavlon and iodine, and the area where the puncture is to be made should be infiltrated with about one cubic centimeter of 1 per cent novocain. The skin is then pierced with the tenotome, the point of which is directed toward the base of the opening of the osteofibrous canal. One should be able to feel the fibers of the tendon sliding under the blade. The blade is then passed under the edge of the canal. Then, working from below up, a cut a few millimeters in length should be made. At the same time, with the tenotome in place, the patient is asked to flex and extend the finger, and, if the jumping movement can still be felt, the incision in the canal should be made longer. This incision should be made exactly over the mid-line of the metacarpal and rigorously parallel to that line (Fig. 6). In this way, it is impossible to injure a nerve or collateral artery located beside the tendon. Even if the tenotome cuts deeper it is in no danger of cutting the tendon because the blade will stay parallel to it. It will not matter if the fibers of the tendon are slightly divided. After the operation, the tenotome is removed and the small laceration is covered with a dry dressing which can be removed after forty-eight hours. Neither suturing nor immobilization is necessary, and the patient can immediately resume work. Slight pain for the next few days over the site of the incision is not unusual.

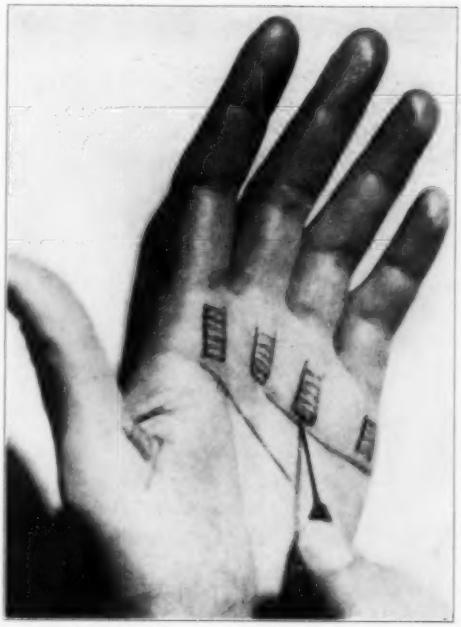

FIG. 6

Position of the tenotome for the incision of the skin and the opening of the canal.

Conclusion

This simple operation can be done without any special preparation in the office.

Fifty-two patients were treated by this method with good results. There were no inflammatory or functional complications. A few patients complained of pain over the area of the incision, but there were no complaints after three or four days.

I would like to insist upon the following few points. In no instance should the nodule be removed. The tendon is a very delicate structure which will not tolerate interference. The removing of the nodule provokes adhesions and sometimes causes rupture of the tendon. In almost any case, the simple incision of the osteofibrous canal is sufficient.

Many surgeons prefer the open method rather than the closed method; but, for this particular condition, I think that this method can be useful to surgeons who are well acquainted with the anatomy of the hand.

Dermal Overgrafting of the Leg

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Loss of overlying protective skin and subcutaneous tissue is often associated with compound fractures, avulsions, or burns of the lower extremity. Skin loss also occurs as a result of vascular disturbances, ulcers, damage from irradiation, and many other causes. Replacement of surface loss occurs naturally by scar formation or is aided by the surgeon who uses a split-skin graft or pedicle flap to close the defect. The resulting skin or scar must cover and protect the underlying anatomical structures from the trauma incident to normal living and from contact with the environment. It must not break down from trivial trauma or when vascular imbalance and venous congestion result in a tendency to ulceration.

There is seldom difficulty from minor trauma in scars overlying the soft-tissue areas of the leg. Over bone prominences, however, especially the pretibial area, abrasion and ulceration frequently occur. When normal skin and areolar subcutaneous tissue are lacking, and a scar or thin-skin graft take their place, difficulty follows. It is not uncommon that a patient, in whom a compound fracture has long since healed, becomes a semi-invalid because of recurring ulceration of the overlying scar. Such dense, shiny, adherent cicatrix resists trauma poorly and the slightest blow, kick, or even friction from clothing can cause a break in the epithelium which heals slowly, if at all.

When possible, the proper treatment of such scarred and fragile areas is usually the application of a pedicle graft, which is done by shifting local flaps, cross-leg flaps, or pedicle grafts migrated from a distance. In young healthy patients, this method works well and should be used, but in older, arthritic, or debilitated patients, it is precluded and covering the surface of the lower extremity is a great and frequently recurring problem. The slightest trauma produces an abrasion which fails to heal and soon becomes an ulcer. If the scar or a previous graft is resected in order to apply a new graft, the underlying areolar soft-tissue cushion usually comes away with the resected tissue. The new graft then has still less resiliency beneath it and frequently rests on periosteum. It withstands trauma less easily than did the earlier scar and the situation is worse than before.

For many years a substitute for a pedicle graft, when a pedicle flap cannot be used, has been sought by surgeons concerned with lower-extremity ulceration. Inspired by the surgical-abrasion technique of Iverson (in which sandpaper is used to abrade the surface of acne scars of the face, remove traumatic tattoos, and other surface defects), the senior author was encouraged to attempt to add healthy-skin covering to scarred areas by placing a thick split-skin graft on top of the abraded, bleeding surface of the scar, without resecting the scar. The application of a thick split-skin graft to a bleeding, raw surface of the intact dermis has been often attempted in the replacement of unused skin grafts on an original donor site. The cysts, sinuses, wrinkles, and scars which result from such a procedure are well known. Why then should one anticipate success in placing a graft on an abraded scar or previous graft? The answer lies in the absence of secondary skin structures, such as hair follicles, sebaceous glands, and sweat glands in the thin scar or in previous thick split-skin grafts. Although the first overgraft which we applied was in 1953 [6], no such complications have arisen and the technique has proved successful in the selected group of cases here presented. In one instance, as many as three separate grafts were piled on top of one another in three separate operations. Each graft took successfully and

FIG. 1-A

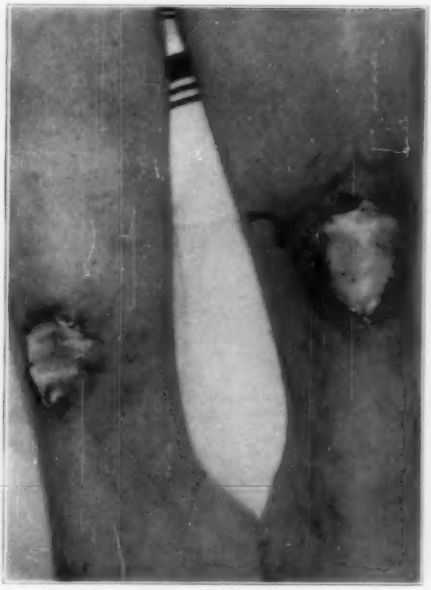

FIG. 1-B

Fig. 1-A: F. K. The bilateral pretibial ulcers are surrounded by thin, shiny, atrophic skin.

Fig. 1-B: Split-thickness skin grafts are seen in place over the abraded skin around the ulcer sites.

completely on the bleeding, abraded surface of the graft or scar beneath it. Benefit thus is derived by the addition of thick dermis with its content of elastic fibers acting as a cushion.

FIG. 1-C

Postoperative condition.

TECHNIQUE

A split-skin graft, .015 inch thick, is taken by a dermatome of the surgeon's choice. The ulcerated area, with a surrounding portion of adjacent skin, is then surgically abraded with Wet-or-Dry 100-D Grit sandpaper. The uneven surfaces of ulcerated or scarred areas easily accommodate manual sandpaper technique. The abrasion is carried out until the epidermis is removed and an actively bleeding surface encountered. The ulcer and adjacent abraded area are irrigated to free them of any particles of silica and the skin graft is attached to the entire abraded area by a number of peripheral sutures, some of which are left long to tie over a fluffed gauze dressing for firm immobilization of the graft to the recipient area. The entire mass is then bandaged firmly in place without constriction.

The usual postoperative regimen includes bed rest and elevation of the extremity

FIG. 2-A

FIG. 2-B

FIG. 2-C

Fig. 2-A: Case 4. C. I. The thin, atrophic, pigmented, pretibial skin is shown in photograph.
Fig. 2-B: The skin is being abraded with sandpaper wrapped around a roller bandage.
Fig. 2-C: The full extent of the abraded skin is being irrigated to remove silica particles.

until the graft is well stabilized, which is about ten days or two weeks. Then gradually increasing activity is begun and support of the extremity with an elastic stocking is used during early ambulation.

Grafts uniformly take well. The technique is particularly applicable to augment the healing of a previous graft which took only partially on an ulcer or when re-ulceration occurs within a skin graft. The transformation of a partial take of a graft, with its spotty areas of thin, healed scar and some areas of good graft, to one of a homogeneous, resilient, thick split-skin graft is dramatic and appears to be definitely beneficial. Obviously, it is better if the first attempt produces a perfect take of a split-skin graft on an excised leg ulcer, but often minor areas of necrosis of the graft result in healing by scar which is frequently no better than the scar replaced by the skin graft originally. These areas tend to re-ulcerate early when the patient resumes walking and regular activity. It is in these cases that abrasion of the surface and overgrafting, rather than repeated resection of a partially ulcerated or scarred first graft, gives the most beneficial results.

CASE REPORTS

The following are the case reports of ten patients consecutively treated at the Huntington Memorial Hospital and Wadsworth General Hospital.

CASE 1. P. F. L., a sixty-year-old white male hospital attendant, had fractured the distal third of the right tibia many years previously. There was recurrent ulceration of the skin over the old fracture site, with three previous partially successful attempts at excision and split-skin-grafting. The last skin graft was done in February 1956. About one-third of the grafted area was occupied by thin unstable scar epithelium and an area of ulceration two by two centimeters. On March 6, 1956, the ulcer, scar, and old skin graft, with an area of adjacent skin, were manually abraded. A thick split-skin graft was applied over this surface. The overgraft survived in entirety, the area has remained healed, and the patient engages in full activity.

CASE 2. A. M., a white male brewery bottler, forty-six years old, struck his left shin while at work on January 4, 1956, causing a pretibial ulcer in an area of thin scarred skin over a healed compound tibial

FIG. 2-D

FIG. 2-E

Fig. 2-D: Split-thickness skin graft is shown after application.
Fig. 2-E: Postoperative photograph, three years later.

fracture sustained twenty-five years previously. There was an anterior bowing deformity of the tibial margin; the overlying skin was thin, pigmented, shiny, and unstable. The patient also had bilateral saphenous varicosities. Bilateral high ligations and saphenous-vein strippings were done on January 6, 1956, as a first stage in reconstruction. The ulcer persisted, but became drier and cleaner. On June 15, 1956, a tibial sequestrectomy was done; the leg ulcer was treated for several days by wet-dressing technique. On June 29, 1956, a skin overgraft was placed on the manually abraded ulcer and adjacent area of thin scarred pretibial skin. On July 30, 1956, the patient was discharged, wearing elastic stockings. He soon returned to work and full activity. On September 21, 1956, the use of the stockings was discontinued and a plastic pretibial guard substituted to avoid future trauma. There has been no recurrence of ulceration.

CASE 3. F. H., an obese housekeeper, sixty-two years old, was admitted on July 18, 1956, with ulcerations of both lower extremities in the pretibial area. These ulcers had been persistent for four months following an injury caused by striking both legs against an ironing board. For two weeks the patient was treated with bed rest, elevation of the lower extremities, and wet dressings to clean the ulcers. On July 30, 1956, with the patient under local anaesthesia, free-hand split-skin grafts were applied to the manually sandpapered areas over the pretibial ulcers and adjacent skin. There was complete survival of the overgrafts and the patient was discharged on August 30, 1956, wearing elastic stockings. There has been no recurrence of the ulcers.

CASE 4. C. I., a white male, thirty-one years old, had had severe acid burns of the face, chest, arms, thighs, and right leg in 1952. Following the injury, repeated skin grafts were applied to cover the burned areas. There was great difficulty in obtaining viable grafts in early months, because the grafts unexplainedly underwent dissolution after first appearing healed. This was later traced to a recurring *Staphylococcus albus* infection. Six skin-graft operations were carried out over a six-month period to obtain complete coverage of the burned areas. The skin graft of the right pretibial area remained thin and unstable. On September 7, 1956, the right pretibial scar and skin graft were surgically abraded by the manual sandpaper technique and a thick split-skin graft was applied over the entire pretibial area. The overgraft supplied additional thickness to the pretibial tissue for protection. There has been no recurrence.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 5. C. E. S. There is an ulcer in the center of a skin graft on an irradiated area of the leg.
Fig. 3-B: Note the build-up on the overgrafted area of tissue over the former ulcer bed.

CASE 5. C. E. S., an aircraft worker, forty-four years old, had received x-ray therapy sixteen years previously for tibial periostitis. For the past seven years, he had had recurrent ulceration of the left leg for which a cross-leg flap transfer had been done in 1953. In 1955, the skin lateral to the cross-leg flap became ulcerated. Roentgenograms revealed no evidence of osteomyelitis, but there was marked tibial and fibular sclerosis and periosteal proliferation. The skin about the lower portion of the lateral aspect of the leg was atrophic, pigmented, dry, and scaly in the area surrounding the previous skin grafts. In May 1956, the ulcer was widely and deeply excised and replaced with a split-skin graft, which had only a partial take. A second skin graft was applied on June 30, 1956, to fill out the defect. Since a small granulating surface remained, abrasion and split-skin overgrafting were done on September 3, 1956. This healed promptly, but several months later a small blister occurred in the graft, then the center of the graft re-ulcerated. Because of the marked irradiation effect of the tissues of the leg, and the failure of a number of grafts, a distant pedicle-flap graft was planned.

CASE 6. R. C. G., a white male postal clerk, thirty-one years old, was hospitalized on July 26, 1956, with a recurrent ulcer of five by seven centimeters on the left leg. The patient had had osteomyelitis of the left tibia following a shrapnel injury in World War II, with recurrent drainage and hospitalizations. Treatment consisting in rest, elevation of the extremity, administration of antibiotics, and wet dressings resulted in marked improvement of the ulcer. The patient was discharged August 10, 1956; he was re-admitted several weeks later with recurrent drainage from the leg ulcer. After several days of rest and the application of wet dressings, a split-skin overgraft was applied to the manually abraded ulcer and adjacent scarred atrophic skin. The graft survived in entirety; the patient was able to resume employment on October 9, 1956. There has been no further drainage.

CASE 7. W. J. L., a white male metal worker, thirty-one years old, was hospitalized on December 12, 1956, with a draining ulcer on the pretibial aspect of the right leg. The patient had had a compound fracture of the right tibia and fibula in an automobile accident in 1953. After fixation of the fracture by a metallic plate, the patient had worn a toe-to-groin cast for a year. Then he had walked, using a leg brace. In January 1955, a screw from the plate pierced the skin and persistent drainage began. In June 1955, the plate was removed and a skin defect developed which had drained constantly; two attempts at skin-grafting had been unsuccessful. When the patient was hospitalized in 1956, there was a foul draining ulcer four by 2.5 centimeters in the medial aspect of the right pretibial area. The adjacent skin was pigmented, shiny, and unstable.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 10. F. E. In this patient there was pretibial ulceration, scaling, and pigmentation secondary to venous insufficiency.

Fig. 4-B: Postoperative appearance following overgrafting procedure.

Roentgenograms revealed no evidence of sequestration, but there was excessive sclerotic callus about the healed tibial fracture site. A cross-leg flap was planned and abrasion with split-skin overgraft was done on January 8, 1957, to gain a healed area for transfer of the flap. The overgraft healed the ulcer bed promptly and completely. On February 12, 1957, the cross-leg flap was transferred and excess bone callus removed. The overgraft and former ulcer site were excised for histological study. The flap was divided and inset on March 13, 1957, completing the reconstruction.

CASE 8. L. A. W., a white male war veteran, sixty-six years old, was hospitalized September 25, 1956, for excision of a large ulcer on the medial aspect of the right knee. Several years previously, a basal-cell carcinoma had been treated in this area by irradiation therapy. The irradiated area ulcerated in June 1956. The skin graft healed initially, but soon a three-centimeter ulcer reappeared in the center of the graft. On June 15, 1957, the central ulcer was excised and the surrounding graft manually abraded with sandpaper. A split-skin overgraft was applied; three weeks postoperatively a small blister again appeared in the ulcer site. The small central ulcer was again excised to greater depth on February 14, 1957, and another layer of overgraft applied on the adjacent skin graft after abrasion. This overgraft healed completely and the patient was discharged to full activity on March 15, 1957. The overgrafts have remained healed.

CASE 9. A. J. F., an obese white male war veteran, fifty-nine years old, had had a pretibial ulceration for seven years associated with deep venous insufficiency. The arterial pulsations were of good quality. The ulcer measured 2.5 by three centimeters in diameter and was surrounded by an area of poor, atrophic, pigmented skin. On March 7, 1957, the ulcer and surrounding skin were surgically abraded and a split-skin overgraft applied. There was complete take of the overgraft and no recurrence of the ulcer has been noted.

CASE 10. F. E., a white male war veteran, forty-three years old, had had ulceration of the leg for many years secondary to venous insufficiency. The area would ulcerate on minimal provocation, slowly scar, and again break down; this occurred in spite of his wearing elastic stockings. On admission of the patient, the pretibial skin was found to be ulcerated, scaling, and surrounded by a zone of pigmentation. The patient was treated by elevation of the leg and administration of antibiotics, following which the area was abraded

manually and a split-thickness graft applied. The usual postoperative regimen was followed and the patient was discharged, wearing elastic stockings. The area has remained healed with the resumption of full activity.

DISCUSSION

The combination of the surgical-abrasion technique of Iverson with the use of split-skin-grafting has resulted in the simple, safe, and useful technique of skin-overgrafting. When this method of skin-grafting was first suggested, objections were raised concerning the potentiality of cyst formation beneath the grafts. In our experience this has not occurred in any of the patients in this series nor in those previously reported. In the free-nipple transplants of mammaplastic surgery, the nipple and areola are actually transplanted as a full-thickness skin overgraft onto the dermis of the breast at a chosen site. In these instances, only the epidermis is excised (essentially removing a circular split thickness of skin) to create the recipient site for the free-nipple transplant. No case is recorded of cystic formation beneath these transplants. The principle of the overgraft technique described in this series does not differ from that of a free-nipple transplant.

A word of caution should be given regarding this procedure. A dermal overgraft should be done only on atrophic, shiny skin which is devoid of hair follicles, sebaceous and sweat glands. If this principle is not followed, inclusion cysts may result. An overgraft may, however, be applied over a previous split-skin graft. The presence of infection or draining sinuses, of course, contra-indicates the procedure.

SUMMARY

The advantages of the overgraft technique are:

1. Preservation of any areolar cushioning tissue beneath old scar, while additional layers of elastic dermis are added. Layer upon layer can be added at subsequent operations to reinforce areas of scar, ulceration, or adjacent poor skin.

2. Simplicity of the method obviates the necessity of deep dissection. A good take of graft is usually obtained.

3. Nothing is lost if the graft should fail, for a large area has not been excised. The grafts tend to withstand time. If ulceration recurs after an overgraft is done, it is usually small and additional overgrafts may be added as required with a minimum operative procedure.

Hynes recently reported the satisfactory treatment of a variety of scar conditions by shaving and skin graft, essentially the same technique as herein described. He emphasized the simplicity of the method and mentioned no adverse complications.

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Torsion of the Femur

A Follow-up Report on the Use of the Dunlap Method for Its Determination*

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New techniques and operative procedures in medicine seldom reach their full maturity and have general acceptance until an adequate trial period has passed and suitable reports have been made to confirm their usefulness. This paper is presented as a four and one-half year follow-up study on the use of a technique for the determination of torsion of the femur. This method was originated by one of the former residents of the Alfred I.

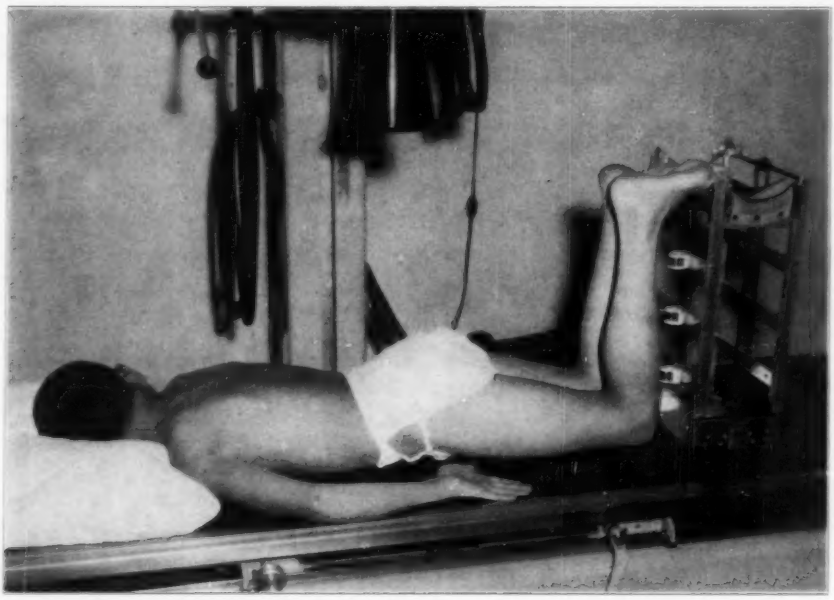


Fig. 1

The patient is in a prone position for a postero-anterior roentgenogram of the hips and pelvis. The hips are fully extended and the limbs are together and perpendicular to the table in order to obtain neutral rotation of the hips.

du Pont Institute, Dr. Knox Dunlap, perfected by the Institute Staff of 1952 and 1953, and first published in 1953 [1]. During the first year of the employment of this method, there were several modifications in the technique, but since August 1, 1952, the method has not been changed. This is a report on 1,409 roentgenographic studies of the hip joints of 584 patients made at the Institute between August 1, 1952, and January 1, 1957.

In the first paper, the authors gave a description of the terminology and a comprehensive report of the literature, with as complete a bibliography as could be prepared at that time. The importance of excessive femoral torsion in the treatment of congenital

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 25, 1957.

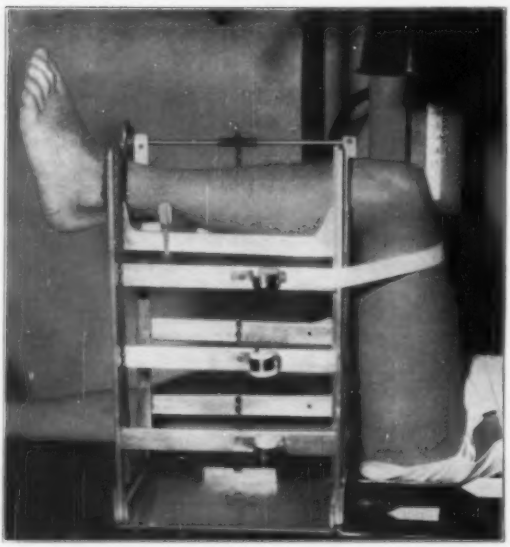


FIG. 2

FIG. 3

Fig. 2: The patient is in a supine position with the left lower extremity in the positioning apparatus for a lateral roentgenogram of the left hip. The left leg is parallel to the table, the knee is at right angles, and the thigh is perpendicular to the table. The large arrow points to the lateral radiopaque bar attached to the positioning apparatus; this is placed lateral to the greater trochanter. The small arrow points to the second radiopaque bar which is at right angles to the lateral radiopaque bar.

Fig. 3: The patient is in a supine position for a lateral roentgenogram of the left hip. Note that the leg and foot are in neutral rotation. The thigh is abducted approximately 10 degrees as determined by the triangular wooden template on the lateral aspect; the line of the medial side of this template is at a 10-degree angle to a line perpendicular to the table. Note that the protruding muscles and soft tissue of the mid-thigh make it difficult to determine accurately 10 degrees abduction using this template; the roentgen-ray tube is placed directly above the hip so that the rays will be at right angles to the film.

dislocation of the hip and the various methods for determining the angle of torsion in the patient were discussed. Many techniques and studies had been described up to 1953, such as the techniques of Stewart and Karschner and Rogers[10,11], and the studies by Kingsley and Olmsted of torsion in dried femora. These will not be repeated; however, we will refer to the studies of certain authors whose findings are related.

The authors hope that some others working on this problem, such as those using the excellent methods described by Dunn, Ryder and Crane, Shelswell, Laage and associates, and Magilligan, may soon have a sufficient number of studies of normal and abnormal hips to compare with these findings. It is believed that the information here reported is important and may lead others to comparable studies; however, there is certainly not a sufficient number of cases in this report from which to draw definite conclusions.

For those readers unfamiliar with the technique referred to in the 1953 publication, the following is a brief description of the Dunlap method of determining the true angle of torsion of the femur:

1. A postero-anterior roentgenogram of the pelvis and hips is made with the patient in the prone position (Fig. 1); the hips are fully extended, the knees are flexed to 90 degrees, and the legs are perpendicular to the table. On this film, the shaft-neck angle or the apparent angle of inclination is measured.

2. A lateral roentgenogram of each hip is made with the patient in the supine position. The lower extremity is positioned in a simple apparatus (Fig. 2) which holds the hip and knee at right angles and which has an attached radiopaque reference bar placed just lateral to the greater trochanter; the thigh is abducted 10 degrees. The abduction of the thigh is determined by a triangular wooden template one side of which forms a 10-degree angle

with the plane of the table (Fig. 3). A second radiopaque bar, attached at right angles to the first bar, represents the transcondylar axis of the femur. The apparent angle of torsion which is the angle formed by this second bar with the central axis line of the femoral neck is measured on this lateral film. The angle of torsion is the angle formed by the plane of the transcondylar axis and the plane of the central axis of the neck.

3. The true, or corrected, angle of torsion is then determined from the angle of measured torsion and the angle of measured inclination with the use of a graph prepared from a special trigonometric formula. (For the complete formula reference should be made to Webber Formula No. 1 and Graph I on pages 299 and 300 of the April 1953 issue of *The Journal of Bone and Joint Surgery*.)

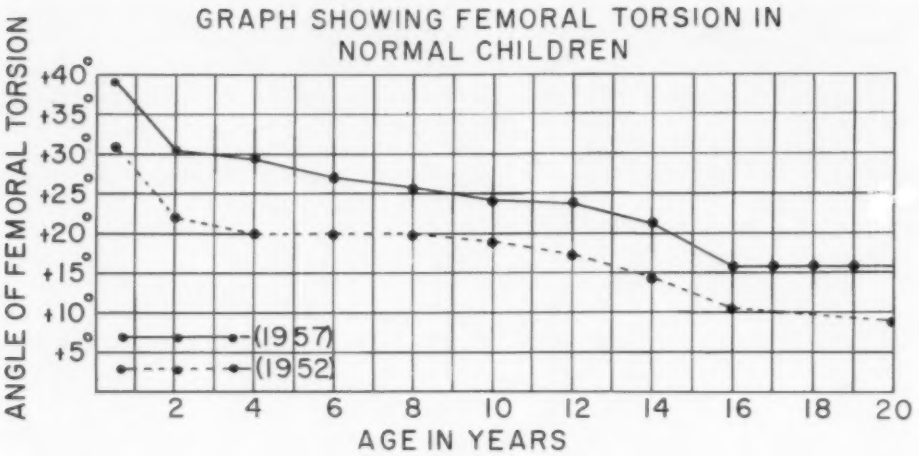
In the original article factors which involved sources of error (proved by experiments with dried femora) were mentioned. These factors are considered here in order to enable us to make an accurate determination. They are the following: (1) the amount of flexion,

TABLE I

DIAGNOSES OF PATIENTS WITH FEMORAL-TORSION STUDIES

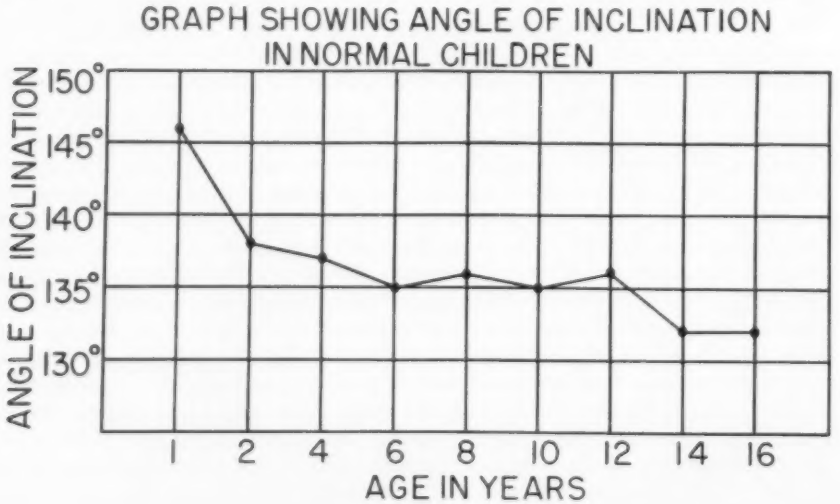
Diagnosis	No. of Patients	Total Studies
Normal hips	249	563
Normal hips in children with associated orthopaedic conditions	189	434
Congenital dislocation	46	142
Coxa plana	34	78
Normal hips with unequal leg length	26	78
Normal hips with bow-leg and knock-knee	13	32
Neuromuscular dislocation	9	18
Coxa vara	7	31
Miscellaneous	11	33
Total	584	1,409

abduction, and rotation of the hip; (2) the angle of inclination of the neck of the femur (shaft-neck angle); (3) the angle of the roentgen ray to the film (this should be perpendicular); and (4) the anterior bowing of the shaft of the femur. Studies on dried femora, subsequent to the original investigations, have shown that this fourth factor, the anterior bowing of the shaft of the femur, is not as important as it was originally thought to be, provided that the lower extremity is carefully positioned for the roentgenogram. An additional source of error in the living patient, not mentioned in the original publication, and which is not a factor in studies on dried bones, is the amount and distribution of the muscle, fat, and subcutaneous tissue of the thigh. If this is excessive and the lateral muscle mass bulges as is shown in Figure 3, it is difficult to align accurately the medial side of the template. This usually results in more than 10 degrees of abduction and an increase in the percentage of error. Because of the many sources of error and in some instances variable readings in hips with high degrees of torsion, some may think that the amount of torsion had best not be expressed in terms of degrees but in terms of a mild, moderate, or severe increase or decrease. However, in this paper, readings in degrees will continue to be used. The human factor as an additional source of error exists, particularly in the positioning of the patient and in the determination of the cervical axis in the roentgenograms. It is believed that in this study the human error has been minimized, since almost all the roentgenograms have been made by the same specially trained technician, who assisted the Institute Staff in the development of the original technique, and all measurements of the roentgenograms have been rechecked by the junior author.



GRAPH I

Of the 584 patients in this report, there were 107 patients (18 per cent) with 302 studies of abnormal hips (Table I). They were as follows: congenital dislocation of the hip, forty-six patients with 142 studies; dislocation of the hip associated with a neuromuscular disorder, nine patients with eighteen studies; coxa plana, thirty-four patients with seventy-eight studies; coxa vara, seven patients with thirty-one studies; and miscellaneous conditions, eleven patients with thirty-three studies. Of the remaining 477 patients with supposedly normal hips, only 249 were considered to be orthopaedically normal. The readings of the roentgenograms of 238 of these patients were the basis for two graphs, one showing normal torsion and the other showing normal angles of inclination. The remaining 228 patients with normal hips include children with limb-length discrepancies, knock-knee, bow-leg, club-foot, claw-foot, pigeon-toe, spina bifida, muscular dystrophy, cerebral palsy, or poliomyelitis. Many separate reports are given of the abnormalities found in this group.



GRAPH II

Normal Patients

The graph showing torsion with relation to age has been prepared from the studies of 238 normal children ranging in age from three months to sixteen years (Graph I). The remaining eleven patients in the group were over the age of sixteen and have not been used because of the varying ages and insufficient numbers. The average normal torsion in the first period from three months to one year was 39 degrees. At the end of the second year this decreased to 31 degrees, and then the decrease was 1 to 2 degrees every two years until the tenth year, when the average was 24 degrees. From the fourteenth to the sixteenth

TABLE II

FEMORAL TORSION IN CONGENITAL DISLOCATION OF THE HIP

Age (*Years*)	Normal Hips			Dislocated Hips	
	Average (*Degrees*)	Range (*Degrees*)	No. of Studies	Average (*Degrees*)	Range (*Degrees*)
0–1	39	28–53	3	69	65–72
1–2	31	7–55	11	49	44–66
2–4	29	12–47	15	47	35–72
4–6	27	10–48	12	53	33–82
6–8	26	7–43	4	40	33–50
8–10	24	5–48	3	55	51–61
10–12	24	3–39	4	47	29–62
12–14	21	5–39	5	42	37–53
14–16	16	−4–34	5	42	24–55

TABLE III

FEMORAL TORSION IN THE NON-DISLOCATED HIPS IN THIRTY-FOUR UNILATERAL CASES OF CONGENITAL DISLOCATION OF THE HIP

Age (*Years*)	Normal Hips			Femoral Torsion in Non-Dislocated Hips	
	Average (*Degrees*)	Range (*Degrees*)	No. of Studies	Average (*Degrees*)	Range (*Degrees*)
1–2	31	7–55	9	36	22–66
2–4	29	12–47	11	41	27–62
4–6	27	10–48	7	30	12–44
6–8	26	7–43	3	27	14–37
8–10	24	5–48	2	37	18–62
10–12	24	3–39	3	31	26–43
12–14	21	5–39	4	31	26–34
14–16	16	−4–34	3	31	21–42

Note: Sixteen of thirty-four hips (47 per cent) had 10 degrees or more above the average normal figure for femoral torsion.

year there was a sharp drop from 21 to 16 degrees. This latter figure was approximately equal to that of Pearson and Bell who, in 1919, stated that the angle of torsion in the long bones of the English skeleton was +15.3 degrees. The broken line on the graph represents the degrees of femoral torsion determined in 215 normal children in 1952 and reported in 1953. These determinations are from 5 to 9 degrees lower than those in this study. The authors believe that the two principal reasons for this difference are: (1) the roentgenograms of the normal children used in the first graph were not all made by the same technician; approximately one-half were made at the Madigan Army Hospital at Fort Lewis, Washington, and (2) most of the roentgenograms used in the first graph were made with 35 degrees of hip abduction. It has been shown in dried bones that this results in a 13 per cent

greater error than with 10 degrees abduction. (See Table II, p. 308, in the 1953 paper [1].)

Graph II has been prepared to show the corrected angles of inclination in relation to age of these same 238 normal children. The corrected angles were obtained from the measured angles of inclination and the corrected angles of torsion using the Webber Formula No. 2 and Graph II on page 300 of the 1953 paper [1]. In Graph II of the present paper, at the age of one year the angle of inclination was 146 degrees; at the end of two years it had decreased to 138 degrees; at four years, to 137 degrees; and then it remained fairly constant until the fourteenth year, when it decreased to 132 degrees and remained the same until the sixteenth year when it increased to 133 degrees.

With the experience gained in the determination of the angles of femoral torsion during the previous five years, the authors consider a variation of 10 degrees above or below the average normal to be within the limits of normal error. It will be noted that there is considerable variation in these findings in supposedly normal hips. However, the readings in 81 per cent of the total patients are within the 10-degree limit of error; 8 per cent of the

TABLE IV

COXA VALGA AND FEMORAL TORSION. ANALYSIS OF NINETY-TWO HIPS WITH A SHAFT-NECK ANGLE OF 155 DEGREES OR MORE

	Normal Hips			Femoral Torsion in Hips with Coxa Valga	
Age (*Years*)	Average (*Degrees*)	Range (*Degrees*)	No. of Studies	Average (*Degrees*)	Range (*Degrees*)
1–2	31	7–55	15	36	21–55
2–4	29	12–47	30	46	27–72
4–6	27	10–48	22	48	23–75
6–8	26	7–43	15	37	18–60
8–10	24	5–48	10	41	22–62

Note: 60 per cent of the studies of patients with coxa valga showed an increase of 10 degrees or more above the normal average reading for femoral torsion, and 46 per cent of the patients had an increase of 10 degrees or more, exclusive of those with congenital dislocation of the hip.

patients have torsion greater than 10 degrees above the average normal, and 11 per cent have less than 10 degrees below the average normal.

In 1914, Parsons, in studying 300 dried femora, stated that torsion was greater in women than in men. This observation was confirmed as five times more girls than boys had femoral torsion greater than 10 degrees above the average normal. Kingsley and Olmsted, in studying dried femora, reported, in 1948, that they found approximately 1 degree more torsion in the right femur than in the left. In the present study, five of the nine age groups had slightly higher torsion readings in the left hip than in the right.

Congenital Dislocation

There were forty-five patients with fifty-six dislocations; thirty-four of these were unilateral and eleven, bilateral; thirty-six were girls and nine, boys. In the total of sixty-two studies of dislocated hips, 83 per cent of the hips had torsion readings of 10 degrees or more above the average figure for normal hips. The torsion in 36 per cent of the dislocated hips was over 50 degrees; in 19 per cent, over 60 degrees; and in 5 per cent, over 70 degrees (Table II). The highest recorded torsion was 82 degrees. Four patients each had a dislocated hip with a normal torsion reading.

Compare the authors' figure of 83 per cent with marked increase in torsion with 68 per cent reported by Leveuf in 1947 and compare the figure of 36 per cent over 50 degrees or more with the 24 per cent reported by Farrell, von Lackum, and Smith, in 1926.

An interesting observation was the amount of excessive femoral torsion in the non-

dislocated or so-called normal hips of the patients with congenital dislocation of the other hip (Table III). Sixteen non-dislocated hips in the thirty-four unilateral cases (47 per cent) had 10 degrees or more above the average normal reading for their age period. The highest readings were 62 and 66 degrees.

The question is always asked, "What happens to marked increase in torsion in a hip once the dislocation has been reduced?" Unfortunately, there were not enough patients followed for a sufficient length of time for the authors to draw conclusions. However, there were three girls who were followed from two to four years after closed reduction who showed a decrease in torsion. All three were approximately two years of age before reduction at the time of the original torsion study. One of these had a decrease from 51 to 38 degrees; a second, from 59 to 42 degrees; and a third, from 48 to 35 degrees. Some authors have stated that a derotation osteotomy should be done on any hip which shows more than 40 degrees of torsion. In these three patients, it is doubtful whether an osteotomy would have been necessary.

TABLE V

COXA VARA AND FEMORAL TORSION

Age (*Years*)	Type	Angles of Inclination (*Degrees*)		Femoral Torsion (*Degrees*)	
		R	L	R	L
4	Congenital	88	132	−18	24
5	Congenital	91	97	− 2	10
8	Congenital	131	87	17	21
8	Congenital	136	73	28	8
3	Developmental bilateral	87	87	1	−13
5	Developmental bilateral	113	120	3	5
9	Developmental bilateral	110	118	7	5

Coxa Valga

Some writers have stated that coxa valga is often associated with an increase in torsion. This observation is confirmed in the present study since ninety-two hips with an angle of inclination of 155 degrees or more showed a 60 per cent increase of 10 degrees or more above the average normal (Table IV). Excluding the patients with congenital dislocation, who normally have a more marked increase in the angle of inclination, this percentage was 46. The largest number of cases was thirty in the two-to-four-year age group. The average angle of torsion of these thirty hips was 46 degrees or 17 degrees above the average normal with a variation of from 27 to 72 degrees. This observation was not recorded in the first paper.

Coxa Vara

In seven patients with coxa vara, ten hips (72 per cent) showed marked decrease in femoral torsion. This observation was not recorded in the 1953 paper. In three of the ten hips there was a true minus torsion (retrotorsion or retroversion) (Table V). Four of the patients had congenital coxa vara with angles of inclination between 73 and 97 degrees. In three of these patients femoral-torsion readings in four hips varied from −18 to +10 degrees. In one hip with congenital coxa vara, the reading for the angle of inclination was 87 degrees; however, the angle of femoral torsion was 21 degrees which is within normal limits. There were three patients with bilateral developmental coxa vara in whom

TABLE VI

CEREBRAL PALSY AND FEMORAL-TORSION ANALYSIS OF TWENTY CASES

Age (Years)	No. of Studies	Femoral Torsion				Angle of Inclination			
		Normal		Cerebral Palsy		Normal		Cerebral Palsy	
		Average (Degrees)	Range (Degrees)	Average (Degrees)	Range (Degrees)	Average (Degrees)	Range (Degrees)	Average (Degrees)	Range (Degrees)
1–2	2	31	7–55	37	36–38	138	123–165	140	133–142
2–4	2	29	12–47	45	43–58	137	124–160	147	141–152
4–6	3	27	10–48	37	21–49	135	121–155	139	128–143
6–8	2	26	7–43	39	30–48	136	121–151	142	141–143
8–10	5	24	5–48	39	22–50	135	121–160	140	126–149
10–12	2	24	3–39	37	34–40	136	125–152	132	123–136
12–14									
14–16	4	16	−4–34	32	20–39	133	124–145	141	135–152

Note: Twenty-seven of the forty hips (67.5 per cent) had an increase of 10 degrees or more above the normal average reading for femoral torsion, and twenty-two of the forty hips (55 per cent) had an increase of 5 degrees or more above the normal average angle of inclination.

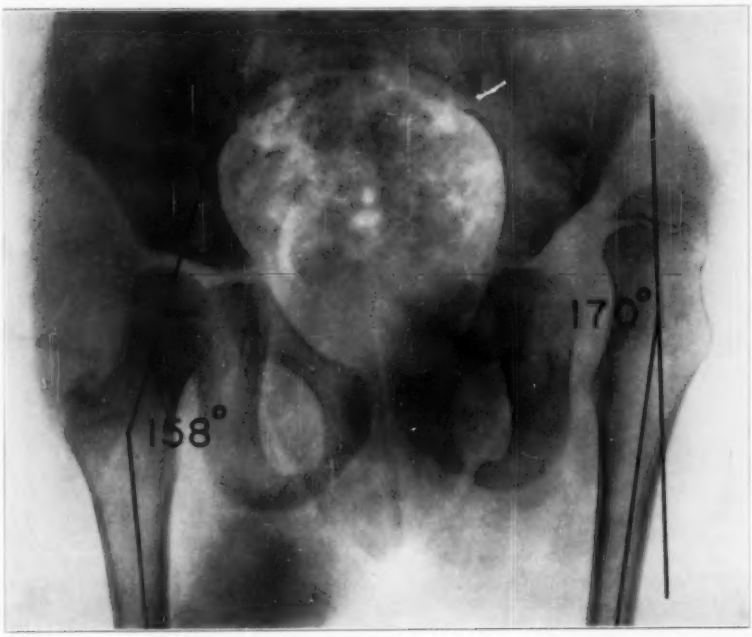


FIG. 4-A

A postero-anterior roentgenogram made of the pelvis and hips in a girl four and one-half years old with congenital dislocation of the left hip. The measured, uncorrected angle of inclination in the roentgenogram is 158 degrees on the right and 170 degrees on the left. The corrected angle of inclination determined by Webber Formula No. 2 and Graph II in the 1953 paper, is 156 degrees on the right and 148 degrees on the left. This type of dislocation has been described as an anterior dislocation.

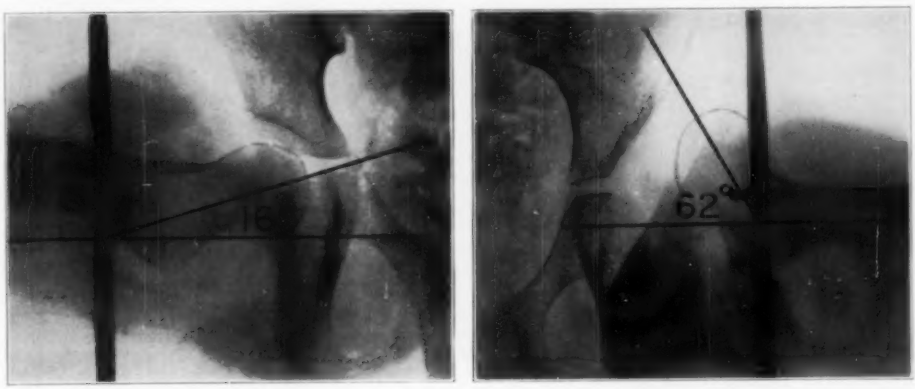


FIG. 4-B

Lateral roentgenograms made of the hips to determine femoral torsion. The uncorrected, measured torsion was 16 degrees on the right and 62 degrees on the left. The corrected torsion determined by Webber Formula No. 1 and Graph I in the 1953 paper is 23 degrees on the right and 75 degrees on the left (46 degrees above average normal)

the angles of inclination were between 87 and 120 degrees. The range of torsion readings for these six hips was from -13 to $+7$ degrees.

Coxa Plana

In this study there were thirty-four patients with coxa plana; twenty-four were boys

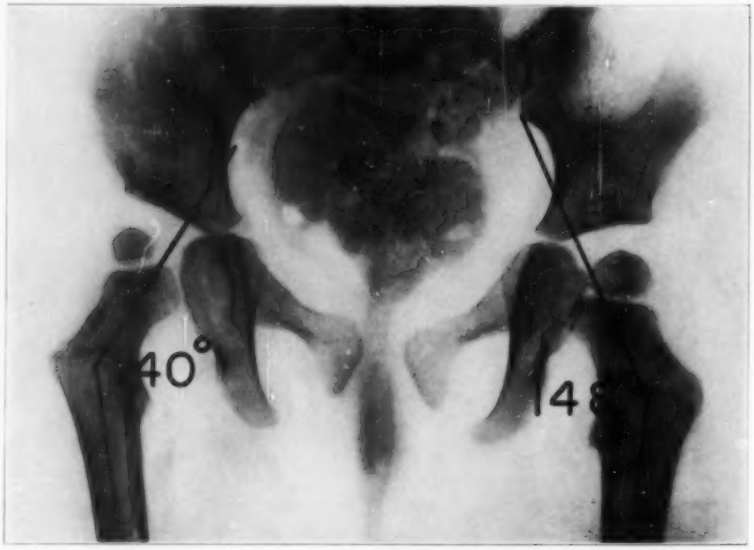


FIG. 5-A

A postero-anterior roentgenogram made of hips and pelvis of a girl two and one-half years old. She had congenital dislocation of the right hip which was reduced ten and one-half months prior to this roentgenogram. There is considerable underdevelopment of the femoral shaft, neck, epiphysis, and an increased slope of the acetabular roof of the right hip as compared with the left hip. The measured angle of inclination is 140 degrees on the right and 148 degrees on the left. The corrected angles are 124 degrees on the right and 128 degrees on the left.

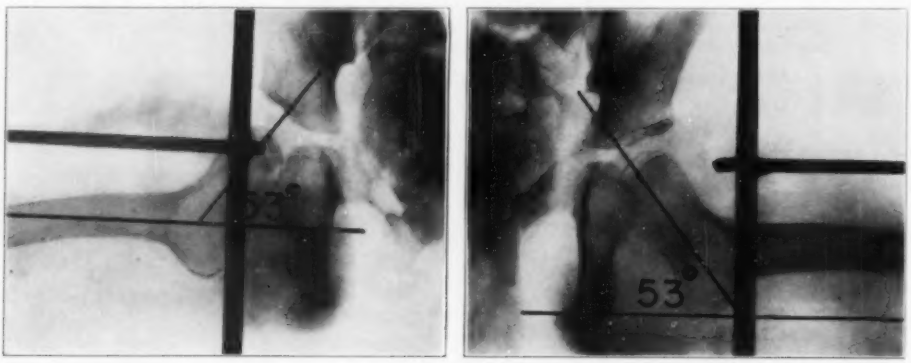


FIG. 5-B

A lateral roentgenogram made of the hips to determine torsion of the femur. The measured uncorrected torsion is 53 degrees on the right and 53 degrees on the left. The corrected torsion is 57 degrees on the right and 58 degrees on the left; these readings are 27 and 28 degrees, respectively, above the average normal. This figure is shown to demonstrate the high torsion readings so often found in the non-dislocated hip of the child with unilateral congenital dislocation.

and ten were girls. Twenty-eight of the cases of coxa plana were unilateral, and six were bilateral. There were six (15 per cent) of the forty hips with femoral torsion increase of 10 degrees or more above the normal average reading for the age period as shown in Graph I. If the normal average for the age period as reported in Graph IV of the 1953 paper is used, ten of the forty hips (25 per cent) have torsion readings of 10 degrees or more above the normal. It is significant, however, that in this second series three of the four children between the ages of two and four had an increase of 10 degrees or more in torsion; these

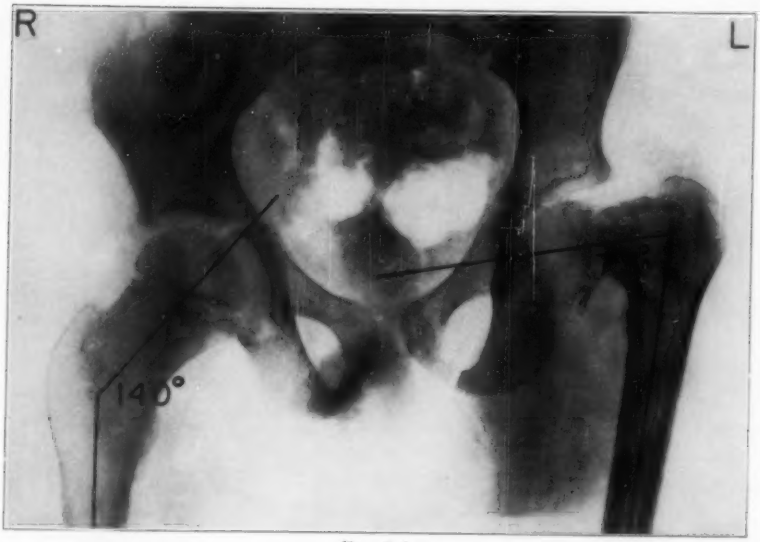


FIG. 6-A

Postero-anterior roentgenogram made of the pelvis and hips of an eight-year-old boy with congenital coxa vara of the left hip. The measured uncorrected angle of inclination is 140 degrees on the right and 73 degrees on the left. The corrected angle of inclination is 136 degrees on the right with no change on the left. There is a shortening of one and three-quarter inches of the left lower extremity.

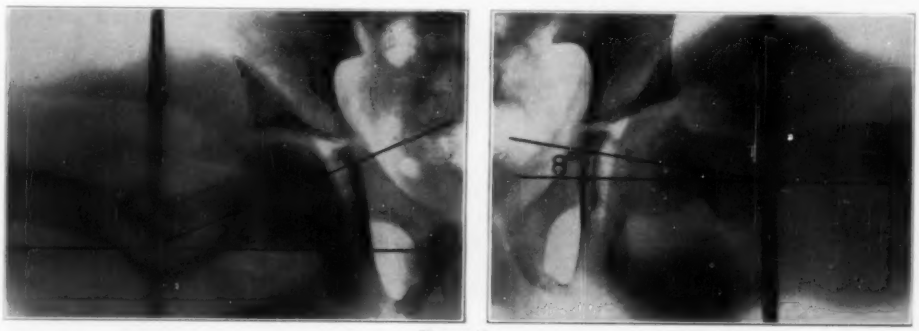


FIG. 6-B

Lateral roentgenograms made of the hips to determine torsion of the femur. The measured uncorrected torsion is 24 degrees on the right and 8 degrees on the left. The corrected torsion is 28 degrees on the right with no change on the left. The amount on the left is 17 degrees less than the anticipated average normal. The amount on the right is within normal limits for his age.

torsion readings were 39 degrees, 42 degrees, and 51 degrees. There were two of the thirteen children in the four-to-six-year age group who showed increased torsion; the torsion was 44 degrees and 45 degrees, respectively.

Cerebral Palsy

It has been stated that most of the hips in children with cerebral palsy have increased femoral torsion. This observation is confirmed. The hips of twenty patients with cerebral palsy have been studied (Table VI). Twenty-seven of the forty hips (67.5 per cent) had an increase of 10 degrees or more above the anticipated average normal. The highest torsion reading was 58 degrees and the lowest 20 degrees. The average angle of inclination of the forty hips (after correction) was 140 degrees as compared with 136 degrees for the normal, or an increase of 4 degrees.

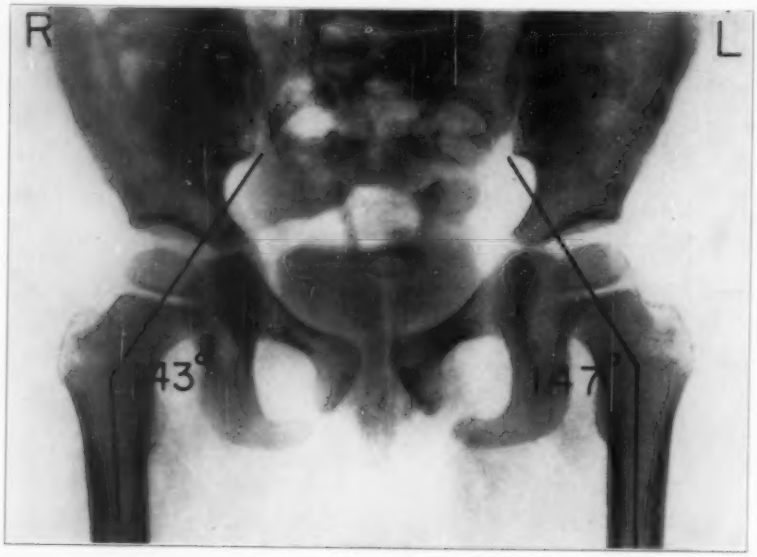


FIG. 7-A

A postero-anterior roentgenogram made of a girl two years and nine months old with a diagnosis of bilateral internal tibial torsion. The measured uncorrected angle of inclination is 143 degrees on the right and 147 degrees on the left. The corrected angle of inclination is 130 degrees on the right and 138 degrees on the left, both within normal limits.

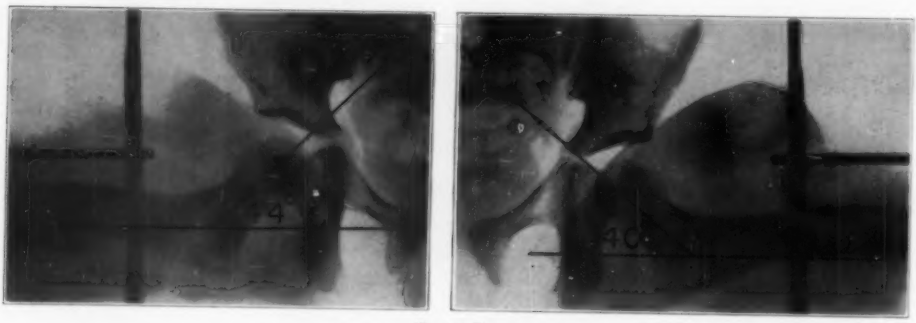


FIG. 7-B

Lateral roentgenograms made of the hips to determine torsion of the femur. The measured uncorrected angle of torsion is 44 degrees on the right and 40 degrees on the left. The corrected torsion is 50 degrees on the right and 47 degrees on the left. These readings are 20 degrees and 17 degrees, respectively, above the anticipated average normal for the child's age. This patient had a history of walking with her toes pointed in for approximately one year, sleeping with her feet turned in, and frequently being found sitting on her feet internally rotated.

Congenitally Short Lower Extremities

In 1953, three children who had a marked decrease in torsion and congenitally short lower extremities were reported. In this series, three children with congenital absence of the fibula and marked shortening of the lower extremity had torsion readings of 4 degrees, 13 degrees, and 15 degrees, respectively. However, most of the children with one lower extremity shorter than the other did not show a decrease in normal torsion.

Internal Rotation of the Tibiae and Pigeon-Toe

There were eleven patients in this group. Six patients had a diagnosis of pigeon-toe;

four had a diagnosis of internal tibial torsion; and one had contracture of the internal rotators. All eleven of these patients showed an increase of 10 degrees or more over the normal average femoral-torsion reading for their age group in one or both hips. There was a range of from 33 to 53 degrees (Figs. 7-A and 7-B). Many of these children slept on their abdomens with their feet turned in. All except two of the children were between one and four years of age. One girl of eight had a contracture of both internal rotators and only 10 degrees of external rotation in the hips, but she habitually sat on her feet with her legs in internal rotation. The torsion readings were 49 degrees on the right and 52 degrees on the left. These observations were not reported in the 1953 paper. These findings seem to have significance in the treatment of tibial torsion and developmental deformities of the legs, but the sample is too small to demonstrate statistical significance.

Poliomyelitis, Neuromuscular Affections, and Other Disorders

One hundred and fifty-one studies were made on fifty-four patients with poliomyelitis. There was no pattern of abnormal torsion determined and no significant findings to report. However, no attempt was made to correlate the cases of abnormal torsion with muscle paralysis or weakness. The same is true of the other neuromuscular hip disorders, such as those found in spina bifida or amyotonia congenita.

It has been believed by some observers that bow-leg and knock-knee may have some effect on torsion of the femur. In the thirteen cases studied in this group there were no significant or unusual findings.

The few studies of slipped upper femoral epiphysis, infection of the hip joint, arthritis, fractures, and other conditions revealed no significant information not reported in 1953.

SUMMARY

1. Fourteen hundred and nine femoral-torsion studies were done on 584 children.

2. Graphs for the average normal torsion of the femur and the average normal angle of inclination (shaft-neck angle) were made for 238 children from three months to sixteen years of age.

3. The significant femoral-torsion information on forty-five cases of congenital dislocation of the hip was reported.

4. In 1409 femoral-torsion studies on 584 children, increased femoral torsion was present in more than one-half of the patients with moderate or marked coxa valga.

5. Six of forty hips with coxa plana (15 per cent) showed increased femoral torsion.

6. A definite decrease in femoral torsion was found in ten hips in seven patients with congenital and developmental coxa vara.

7. Eleven patients with pigeon-toe, internal tibial torsion, and contracture of the internal rotators of the hip showed an increased reading of femoral torsion, but the sample is too small to be statistically significant.

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DISCUSSION

DR. JOHN R. MOORE, PHILADELPHIA, PENNSYLVANIA: This paper is a genuine contribution to our knowledge of torsion of the femur. The material available for the study of the normal femoral torsion and the abnormal femoral torsion shows a decided trend which justifies the authors' present conclusions. However, there is hardly sufficient material for the establishment of a normal base line in the normal or the pathological groups (congenital dislocation of the hip, coxa plana, coxa valga, coxa vara, cerebral palsy, and miscellaneous groups).

Although the present technique has stood the test for five years, the revision of figures in coxa plana and the plus or minus ten margin of error in the normal anteversion figures would suggest a longer cooling-off period before base lines are acceptable.

My brief experience with the method in conjunction with Dr. G. C. Bird, Professor of Radiology at the Temple University School of Medicine in Philadelphia, has led me to believe that the principle involved in this study is sound, and that the roentgenographic technique as well as the interpretation of the findings should be supplied by a competent roentgenologist.

DR. H. RELTON MCCARROLL, ST. LOUIS, MISSOURI: Dr. Shands and Dr. Steele have given us an accurate method to measure the degree of femoral torsion. There are some conditions in the extremity in which the accurate measurement of torsion may be of considerable importance. One of the problems discussed concerned variation in general alignment with the patient walking and the extremity in internal or external rotation. This may indicate some variation in the degree of femoral torsion and its accurate measurement may be of considerable importance. It is possible, in fact, that accurate measurement of this torsion may help to decide whether or not surgical intervention is justified in these patients.

In the problem of congenital dislocation of the hip and congenital dysplasia, where femoral torsion is clinically most significant, there is debate whether or not accurate measurement of the degree of femoral torsion is worth while. From a practical standpoint, the most important factor in determining the degree of femoral torsion in these patients is to find a stable position for the hip at the time of reduction. With the use of preliminary skeletal traction, the soft tissues about the hip can be relaxed to the extent that with no trauma and very little effort, the femoral head can be moved in and out of the acetabulum at the time of reduction and the position of maximum stability can be easily determined. If it is necessary to place the extremity in a position of internal rotation in order to maintain stability, this indicates the degree of torsion which is present. Once determined, this position is maintained until the torsion has been corrected by derotational osteotomy. It would seem, therefore, that accurate measurement of femoral torsion is primarily of academic interest in the problems of congenital dysplasia and congenital dislocation of the hip.

The Iliotibial Tract

Clinical and Morphological Significance*

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In the following study, the author has attempted to establish the relationship of the iliotibial tract to the tensor fasciae latae muscle; the relationship of the tract to the knee joint; the actions of the tensor fasciae latae; and the role of the iliotibial tract and the muscle in contractures of the hip and knee joint.

The iliotibial tract [18] was described in man, in connection with the tensor fasciae latae muscle, as a thickening of the fascia, extending from the muscle to the knee and acting as a tendon of insertion into the lateral tubercle of the tibia (the tubercle of Gerdy). Contractures of the tensor fasciae latae and its tract, or band, have been studied by orthopaedic surgeons in recent years as a cause of deformities in the lower extremity.

The descriptions of the function of the muscle and the tract have varied notably. However, it is obvious that the function of this muscle and the iliotibial tract fascinated even the early anatomists. Vesalius [26] grouped the muscle with the other muscles of the tibia, and called it the sixth muscle of the tibia.

In the anatomical treatises of the eighteenth and nineteenth centuries, detailed descriptions are found. Douglas described the muscle under the name *membranosus* and mentioned that: "Its use is to extend the leg, and turn it a little outwards; and by virtue of its large Aponeurosis, it mightily strengthens the action of the muscles, over which it is spread, by keeping them tight in their places. . . ."

Winslow gave the most accurate description. He said that the body of this muscle is placed between two layers of the fascia lata and is attached by short tendinous fibers which decrease toward the area of the greater trochanter and the tendon of the glutaeus maximus. Thus, it is not necessary to consider the fascia lata or the large band as an expansion of the tendon of this muscle. Winslow called the muscle *muscle du fascia lata.* He said that this muscle had been improperly considered an abductor of the thigh, because the direction of the motor fibers of this muscle is against movement of abduction or of spreading. It is, he felt, very appropriate for rotation or rolling of the thigh from in front inwardly—a direction opposite to the rotation produced by the pelvitrochanteric muscles and the obturator internus. The rotation of the thigh inward is not as limited as is the rotation by the pelvitrochanteric muscles because it can be accomplished with the thigh flexed or extended.

Albinus described the muscle under the name of tensor vaginae femoris or muscle of the fascia lata. He explained its function as a real tensor of the fascia lata causing compression of the muscles contained within the fascia, thus providing stability to these muscles. Since the fascia lata envelops the thigh entirely, the tensor fasciae latae can depress the pelvis both to the side and to the front and also turn the femur inward, or, according to the direction, turn the pelvis outward.

The most thorough and extensive monograph on the anatomy and functions of the iliotibial tract was written in 1843 by Jacques Maissiat. He attempted to explain many physical phenomena in animals and man by applying mechanical principles. The greatest

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 26, 1957.

part of the test was devoted to the study of human and animal locomotion and the role of the *ilio-trochantero-tibiale bande*.

Maissiat considered the *ilio-trochantero-tibiale bande* to be a ligament connecting the ilium with the knee and playing the principal part in maintaining the balance of the body in stance and motion. The tensor fasciae latae muscle was considered of secondary importance and intervening only under special conditions. The publication of this monograph was responsible for the widespread adoption of the eponym *the band of Maissiat*. The analysis of the mechanics given by Maissiat was detailed, although complicated and somewhat confusing for the average anatomist and clinician. Involved theological and philosophical ideas made it even more confusing. The following translation may characterize the basic ideas of Maissiat. In one of the chapters after a description of locomotion in some animals he stated that man's pre-eminence which shines among all other animals is due anatomically and primarily to the existence of the ilio-trochantero-tibial band. Thus man only, who possesses this band of superior elastic nature, associated with a small muscular body, also possesses by virtue of this exceptional gift, the natural primary right, there inscribed, to walk upright on earth, to stand up straight, utilizing the full height of his vertebral column, to see and understand everything around him; to dominate and subjugate by his arm, always free and armed with intelligence, everything which could revolt.

Maissiat's descriptions of anatomical structures were not anatomical descriptions. Many of his statements, anatomical and otherwise, were inaccurate. He believed that dislocations of the hip in adduction and extension were preceded by rupture of the iliotibial band because the band stabilized the femoral head in the acetabulum. He also thought that a cadaver placed on a flat table on one side, with the corresponding thigh flexed, would maintain the other thigh in abduction, off the table by the tension of the iliotibial band. Maissiat's conclusions were accurate mechanically, but his deductions were less important than the observations of the earlier anatomists.

The observations of the French neurologist Duchenne were based on extensive clinical work. They are of much importance. He found that, under direct slight stimulation of the muscle, the soft tissues of the lateral aspect of the thigh which cover this muscle and the vastus lateralis move forward and inward, forming a deep depression over this region. On stronger stimulation, the thigh rotates medially; at maximum stimulation, the thigh is flexed slightly forward and outward with simultaneous medial rotation. There is no abduction of the thigh and no extensor action on the knee.

In patients with poliomyelitis, which Duchenne called atrophic paralysis of childhood, he observed the tensor fasciae latae contract and retract. "In time, or under the influence of treatment, motion returned in certain muscular groups, while paralysis and atrophy persisted in various degrees in some other muscles. Thus, flexion of the thigh returned gradually, while the antagonists remained completely inert. . . . The tensor fasciae latae retracted progressively until the thigh could not be extended. . . . In my little patients the action of iliopsoas was either abolished or weakened, so that voluntary flexion of the thigh was produced principally or only by the tensor fasciae latae which contracted with much force. . . . If the tensor fasciae latae really produced extension of the leg, I could have easily observed it in the previous case where the vasti and rectus femoris did not exist. . . . However, not only did the contracture of this muscle, which held the thigh in continuous flexion, leave the tibiofemoral joint completely free, but when the patient wanted to contract the tensor fasciae to flex the thigh, there was not the slightest action of extension of the leg."

J. Henle in 1871 apparently came to the same conclusion that the tensor fasciae latae does not transmit any action to the knee joint. Sappey in 1888 found no abductor action, nor did he find knee action exerted by the tensor fasciae latae. On the other hand, Braus contended that in certain individuals the muscle can fix the extended knee joint, although

its action is much stronger as a flexor of the hip joint. It flexes the thigh and pulls the pelvis toward the femur in standing. It rotates the femur inward and somewhat abducts it.

Manouvrier, who is quoted frequently in the French anatomical literature, made a study of the tensor fasciae latae under diverse conditions of activity of the lower extremity. He dismissed the action of the muscle as a tensor of the fascia, and asserted that the flexor component is secondary to the rotatory component which turns the thigh inward. He found no extensor action on the knee, but considered the muscle to be a strong abductor of the thigh, producing lateral inclination of the pelvis. The iliotibial tract is not mentioned in connection with the activity of the muscle. Manouvrier's study is based entirely on palpation of the muscle in activities of the lower extremity and has a limited value.

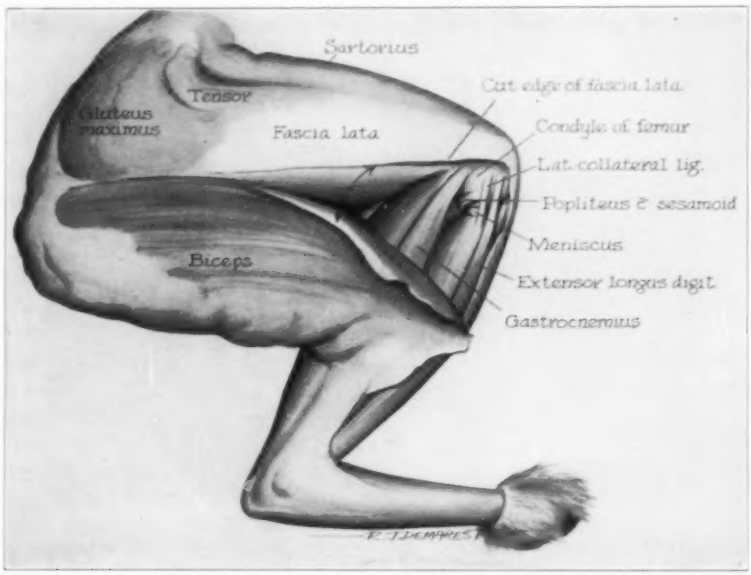

FIG. 1

The right lower extremity of a domestic cat. The tensor fasciae latae blends into the fascia lata and is directly connected with the large biceps femoris which covers the lateral aspect of the knee and leg. The expansion of the biceps femoris is incised to show the structures deep into the biceps. Of interest is the origin of the extensor longus digitorum from the lateral femoral condyle. There is no iliotibial tract.

The modern textbooks of anatomy in English present a variety of views on the action of the muscle and also on its relation to the iliotibial tract. Bryce described the tract as deriving from the glutaeus maximus and tensor fasciae latae—a band which inserts on the lateral tubercle of the tibia (the tubercle of Gerdy), the patella, the linea aspera, and the lateral condyle of the femur. This is the most accurate description. Grant described the action of the muscle as a flexor, abductor, and medial rotator of the thigh, when the leg is free. With the leg fixed, the muscle acts on the pelvis producing flexion, abduction, and lateral rotation. Its action keeps the extended knee extended, and the flexed knee flexed, and "rotates the tibia lateralward at the knee-joint after medial rotation." Patterson and Lockhardt described the band as a blending of fibers of insertion of the glutaeus maximus and tensor fasciae latae. They stated that "The tensor fasciae latae assists in flexion, abduction and medial rotation of the thigh, but its most important action is exerted in counteracting the backward pull of the glutaeus maximus on the iliotibial tract; by this action, it assists in maintaining extension of the knee, and it has, therefore, been found a suitable muscle to transplant as a substitute for a paralysed quadriceps femoris."

Paturet, in a most recent textbook of anatomy in French, stated that a careful dissection of the tensor fasciae latae muscle and the iliotibial tract permits one to observe that the fibers of insertion can be traced from the muscle to the tibia, and that the actions produced by the muscle are tension of the fascia and rotation of the thigh. Otherwise Paturet follows the conclusions of Manouvrier.

The most accurate description of the action of the tensor fasciae latae and its relationship to the tract is given by Hamilton and Appleton. They stated that "Though attached through the iliotibial tract to the tibia beyond the knee joint, the tensor fasciae latae appears to play no direct part in controlling the knee joint movements; it contributes, however, to the stability of the knee joint. The tensor acts principally as a flexor and medial

FIG. 2

The right lower extremity of a dog. The knee joint is at the upper extreme right. *A* represents the tensor fasciae latae which inserts into the fascia lata; *B* represents the glutaeus superficialis or maximus; *C* corresponds to the vastus lateralis; and *D* represents the large biceps femoris which extends toward and over the lateral aspect of the knee joint. The line corresponding to the lateral intermuscular septum is visible, but there is no iliotibial tract. The length of the thigh is sixteen centimeters.

rotator of the thigh, its flexor action is especially important when the thigh is semiflexed. When the knee is extended, the contraction of the muscle exerts pressure on the subjacent vastus lateralis and assists thereby in ensuring the stability of the knee joint. The muscle hypertrophies if the psoas is paralysed." Last considered the iliotibial tract a thickening of the fascia lata with three-fourths of the glutaeus maximus and the tensor fasciae latae inserted into it at the level of the greater trochanter. Passing down, it crosses the lateral condyle of the femur and is inserted into the lateral condyle of the tibia. When the knee is extended the tract maintains the knee in the extended position, but it is not an extensor of the flexed knee. The lateral intermuscular septum in the lower part of the thigh is attached to the iliotibial tract. The chief value of the tract is its stabilizing influence on the knee joint.

A review of the literature of the eighteenth and nineteenth centuries shows that the anatomists had an accurate understanding of the function of the tensor fasciae latae muscle and of the comparative independence of the iliotibial tract. It is possible that later on, under the influence of investigators who considered the lower extremity in gait as subject to the laws of the pendulum, incorrect interpretations were introduced. Under the influence of clinical observations, new data were collected. Duchenne made one of the

greatest contributions by applying his method of electrical stimulation of muscles in normal individuals and in patients afflicted with various types of paralysis.

The author made a study of the tensor fasciae latae by means of several methods. Comparative anatomical studies and multiple detailed dissections of the human extremities were made. Electrical stimulations of the structures under general anaesthesia were performed. Observations were made of patients who had poliomyelitis and of patients in whom surgical treatment required section or removal of the iliotibial tract.

COMPARATIVE ANATOMY

The following animals were dissected and studied: three Rhesus monkeys, one lemur, two gibbons, one orangoutang, three chimpanzees, one gorilla, one American bear, one lion, one alligator, one iguana, two bullfrogs, and several cats and dogs.

In most of the mammals and in the anthropoids, the biceps femoris forms a wide sheet of insertion which covers the entire lateral aspect of the knee, passing over the head of the fibula and the lateral tuberosity of the tibia without insertion into either of these two structures. In some animals, for example the American bear, the bicipital expansion, while passing over the lateral tuberosity of the tibia, inserts into the tuberosity. There is a tensor fasciae latae but no iliotibial tract. Shepard found the same arrangement in his description of the bear.

In the carnivora, as represented by the cat, the lion, and the dog (Figs. 1 and 2), the fascia of insertion of the biceps femoris spreads out and fuses into the fascia lata covering the knee and the leg, not leaving any space for insertion of another structure into the lateral femoral condyle. There is a tensor fasciae latae but no iliotibial tract.

The gibbon has no distinct iliotibial tract. The tensor fasciae latae originates mostly from the gluteal fascia and from a small area below the superior anterior iliac spine. A small muscular body descends toward the tensor fasciae latae and blends with the fascia in the region of the glutaeus maximus. There is no iliotibial tract. The biceps femoris forms an aponeurotic expansion passing over the lateral tubercle of the tibia and establishing intimate connections with the lateral collateral ligament in the region of the fibular head (Figs. 3-A and 3-B).

In the orangoutang, there is no indication of a separate differentiated iliotibial tract, although a tensor muscle is found (Fig. 4). Barnard considered the tensor fasciae latae in the orangoutang as an anterior fasciculus of the glutaeus minimus.

In the gorilla, the muscle is thin and not very wide; it ends by fusion into the fascia lata. There is no iliotibial tract. Duvernoy named the tensor *ileo-fascien* indicating its only relationship to the fascia.

The chimpanzee has a fairly developed tensor fasciae latae but no distinct iliotibial tract follows the muscular body. However, under the aponeurotic expansion of the biceps there is a short outline between the lateral condyle of the femur and the lateral tubercle of the tibia (the tubercle of Gerdy) which may, perhaps, be interpreted as an independent distal part of the iliotibial tract (Figs. 5-A and 5-B).

Vallois' studies of the primate knee established the pattern of relationship of the insertion of the biceps femoris to the tensor fasciae latae between this muscle and the vastus lateralis. Only in the human lower extremity is there an open space between the tendon of the biceps femoris and the vastus lateralis muscle at the knee joint which permits passage of the iliotibial tract for insertion into the lateral tubercle of the tibia (the tubercle of Gerdy). In the monkeys, the biceps femoris ends in a wide aponeurotic sheet which is not inserted into the tip of the fibula but spreads out into a wide expansion which fuses with the fascia lata over the lower portion of the thigh, the knee, and the fascia of the leg, completely covering the space between the biceps femoris and vastus lateralis and the tibia. In the anthropoid apes, the insertion of the biceps femoris recedes from the lower end of the lateral aspect of the femur, although not enough to uncover the lateral tubercle of the tibia (Figs. 6-A and 6-B).

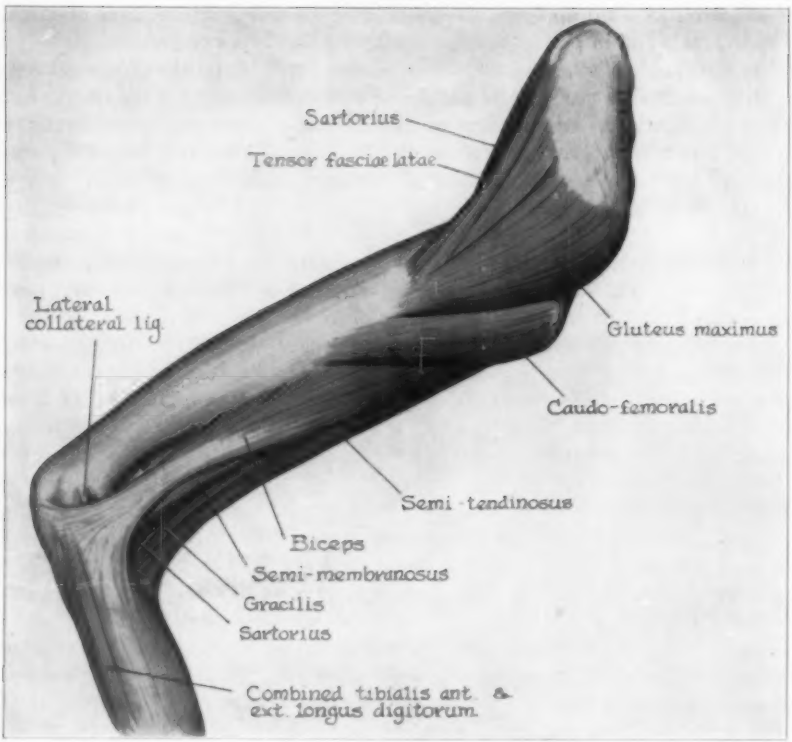

FIG. 3-A

FIG. 3-B

FIG. 4

Fig. 3-A: The left lower extremity of an adult gibbon showing the absence of the iliotibial tract, the manner of ending of the tensor fasciae latae and the glutaeus maximus in the fascia lata. The biceps expansion covers almost entirely the lateral aspect of the knee joint.

Fig. 3-B: Same as Fig. 3-A with the biceps expansion divided to show its insertion into the lateral tubercle of the tibia (the tubercle of Gerdy) instead of the iliotibial tract as observed in man.

Fig. 4: The right lower extremity of a young orangoutang. The lateral aspect of the buttock, thigh, and leg is shown after removal of the skin. There is no distinct iliotibial tract. The depression corresponding to the intermuscular septum is seen between the vastus lateralis and the biceps femoris. The tendon of the vastus lateralis expands over the lateral aspect of the knee. The length of the thigh is about twenty-eight centimeters.

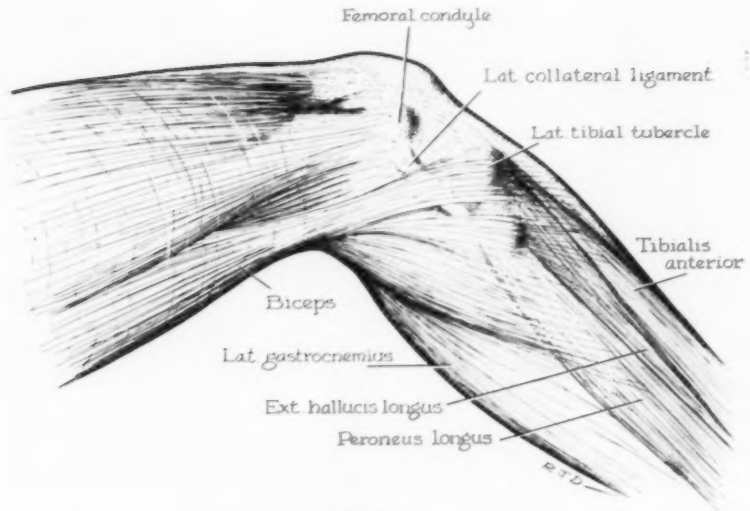

FIG. 5-A

Lateral aspect of the right lower extremity of an adult chimpanzee. The biceps femoris expansion covers the lateral tibial tubercle (the tubercle of Gerdy), lateral aspect of the knee, and the leg. There is no iliotibial tract.

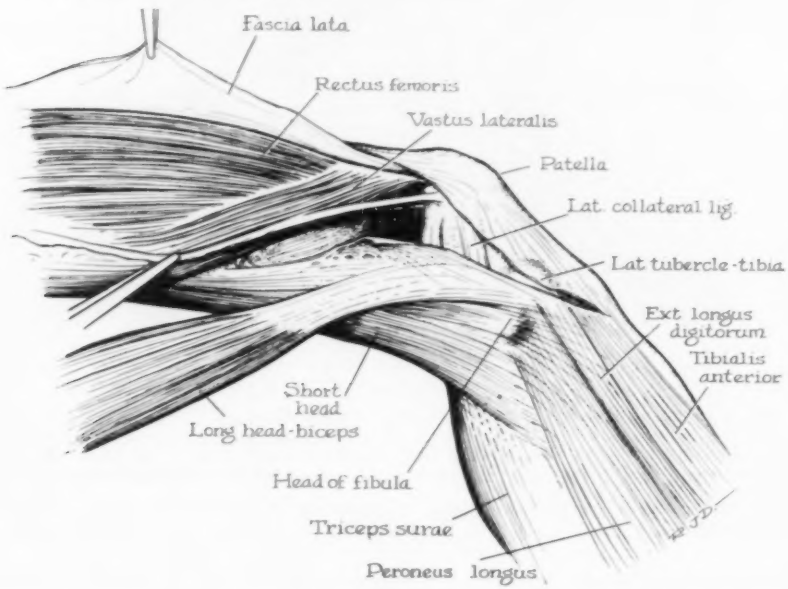

FIG. 5-B

The fascia lata is incised to show the lateral intermuscular septum inserted into the upper portion of the lateral femoral condyle. The expansion of the biceps femoris is inserted into the lateral tubercle of the tibia (the tubercle of Gerdy).

Bluntschli investigated the fascia lata in the primates and concluded that the fascia lata is thicker in man because of the development of the tensor fasciae latae and the iliotibial tract. The fibers of the tract extend not only to the outer border of the patella but even to the medial intermuscular septum.

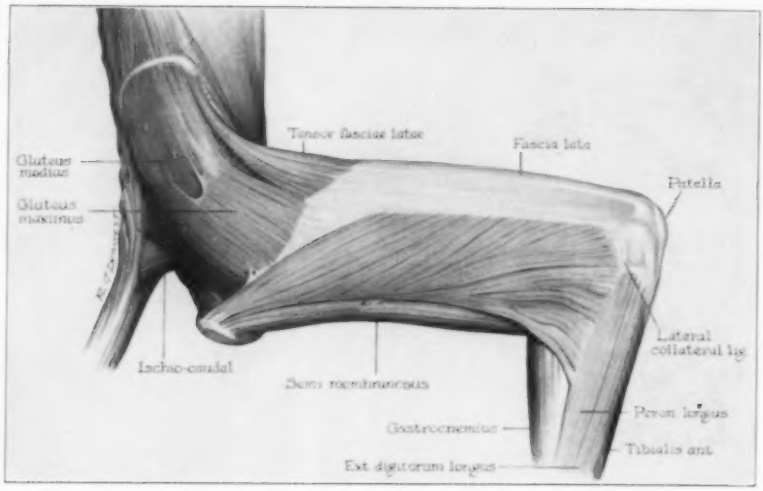

FIG. 6-A

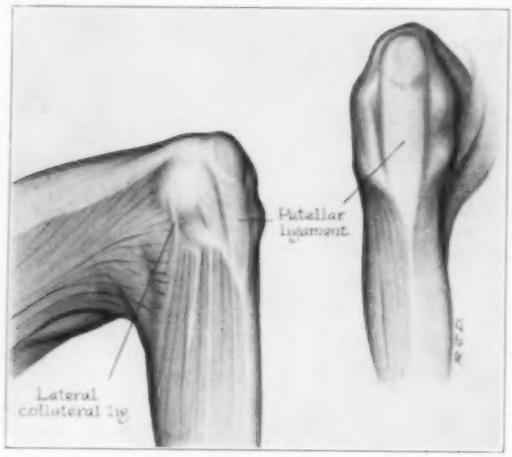

FIG. 6-B

Fig. 6-A: Lateral view of the lower extremity of a Rhesus monkey. The insertion of the tensor fasciae latae, as well as the insertion of the glutaeus maximus, is represented by direct blending without any iliotibial tract. The biceps femoris is wide and covers the lateral aspect of the knee joint. The tendon of the muscle covers the lateral collateral ligament and the lateral condyle of the femur.

Fig. 6-B: Same as Fig. 6-A but showing the knee from its anterior aspect. There is no iliotibial tract.

It is somewhat difficult to come to definite conclusions concerning the structure of the tensor fasciae latae in reptiles and amphibia. The difficulty resides in the nomenclature and radical difference in the arrangement of the axis of hip and knee movements in relation to the pelvis.

There is no animal among the mammals, as revealed from the literature and personal observations, which shows the existence of a distinct iliotibial tract. On the other hand, there is apparently no animal which does not possess a tensor fasciae latae muscle, either independent or as a part of the gluteal group. In all of these, the tensor fasciae latae ends high in the thigh blending with the fascia lata.

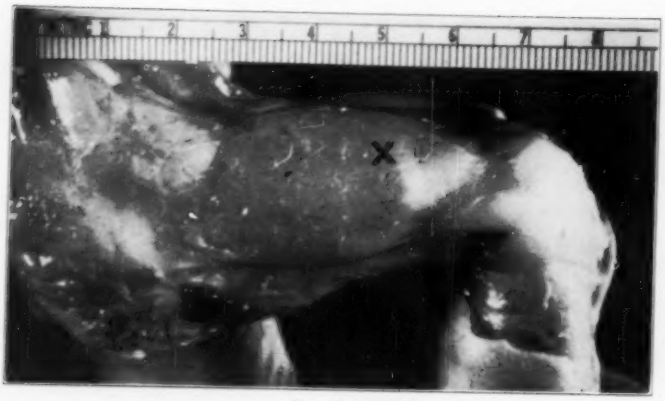

FIG. 7-A

Lateral aspect of the right buttock, thigh, and flexed knee of a premature human stillborn infant, twenty-six to twenty-eight weeks old, with the skin removed. The large mass of the thigh is the vastus lateralis. The iliotibial tract is hardly visible except near the knee where it is discerned as a separate structure from the underlying tendon of the biceps. The length of the thigh is about six centimeters from the greater trochanter to the articular line of the knee.

FIG. 7-B

Fig. 7-B: Same as Fig. 7-A. The fascia lata was incised over the vastus lateralis and retracted to show its insertion into the lateral septum and supracondylar tubercle. The patellar ligament is divided.

On the basis of this discrepancy, it may be suspected that the iliotibial tract is an independent structure and is not necessarily a part of the tensor fasciae latae muscle. The development of the large glutaeus maximus in man and the change of position of the pelvis from horizontal in the quadruped to almost vertical in man contributed to the development of erect posture and a strong fascial band, an anterolateral ligament of support—the iliotibial tract. This tractlike ligament, intimately connected with the lateral intermuscular septum of the thigh, which stops in the lateral supracondylar area of the lateral femoral condyle, extends across the lateral aspect of the knee for insertion into the lateral tibial tubercle. The tendon of the biceps femoris recedes to an insertion to the fibular head to share this area with the lateral collateral ligament of the knee joint.

ANATOMY OF THE TENSOR FASCIAE LATAE MUSCLE AND THE ILIOTIBIAL TRACT

Dissection of premature and full-term stillborn infants showed that the tensor fasciae latae muscle represents a part of the gluteal group. The iliotibial tract is represented by

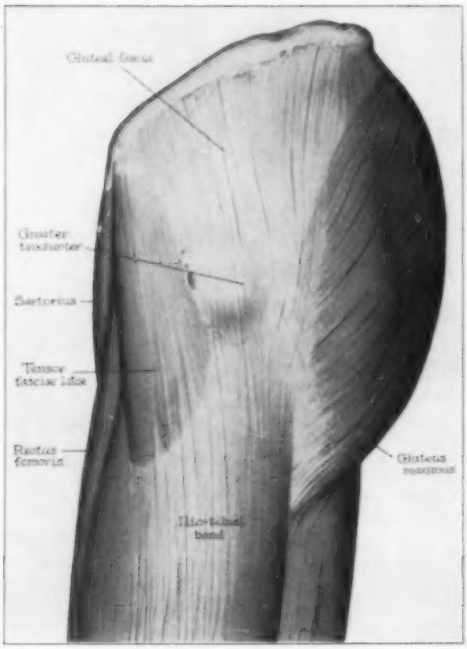

FIG. 8-A

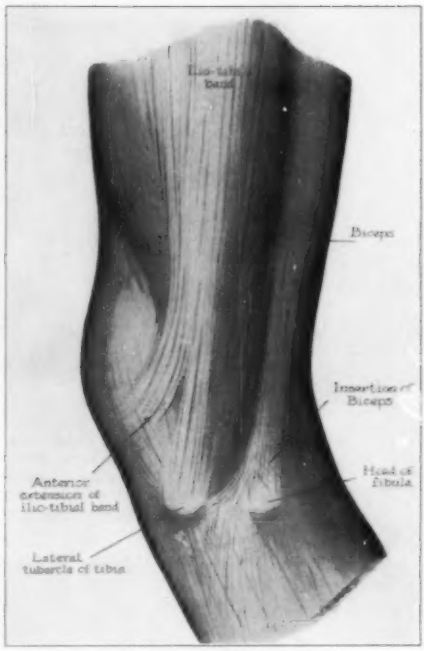

FIG. 8-B

Fig. 8-A: Lateral aspect of the human thigh showing the relationship of the iliotibial tract to the crest of the ilium and the tensor fasciae latae. The muscle is actually in front of the tract. The glutaeus maximus joins the tract from behind. The depression corresponding to the lateral septum is seen.

Fig. 8-B: The iliotibial tract is shown in its distal course and in relation to the patella, tendon of the biceps femoris, and lateral tubercle of the tibia (the tubercle of Gerdy).

Fig. 8-C: The iliotibial tract is detached from the iliac crest, the fascia lata is incised parallel and slightly anterior to the intermuscular septum along the posterior border of the vastus lateralis. The incision is carried across the middle of the thigh. The iliotibial tract and fascia lata are reflected medially to show their relationship to the area.

Fig. 8-D: At the anterior point of the incision across the thigh, another incision is made along the anterior border of the vastus lateralis to the knee joint, and the fascia lata and the iliotibial tract are reflected laterally.

longitudinal fibers which are not entirely differentiated from the fascia lata (Fig. 7-A). These longitudinal fibers adhere firmly to the lateral intermuscular septum between the biceps and vastus lateralis. On flexion and extension of the knee, the fibers move, as a tense longitudinal band, forward or backward. The band adheres throughout its length with the septum to the linea aspera and to the upper portion of the lateral femoral condyle (Fig. 7-B).

In the adult, the tensor fasciae latae originates from a small area just lateral to the origin of the sartorius over the anterior superior iliac spine, from an area about two or three centimeters along the crest of the ilium and from a small area of the anterolateral surface of the iliac fossa, blending its fibers with the fibers of the glutaeus minimus. There is also an origin from the deep surface of the gluteal fascia (Fig. 8-C). The muscle is about fifteen centimeters long, about four centimeters wide, and is of moderate thickness. The size of the muscle does not suggest, in the average case, great power. The fleshy fibers of the muscle descend to an area below the greater trochanter and blend with the fascia lata. Examination of the muscle on its deep surface shows that the fibers of the muscle blend into the fascia lata and deep surface of the iliotibial tract, posterior to the main fibers of the tract. The iliotibial tract is actually stretched behind the muscle between the iliac crest and the knee (Fig. 8-A). With the iliotibial tract transected in the middle portion of the

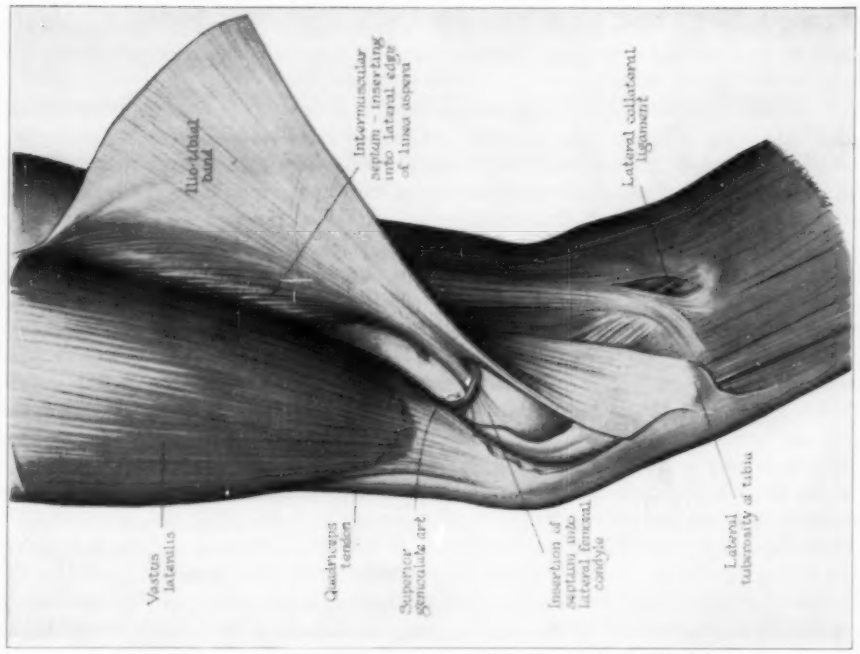
Ilio-tibial band
Intermuscular septum - inserting into lateral edge of linea aspera
Lateral collateral ligament
Vastus lateralis
Quadriceps tendon
Superior genicular art
Insertion of septum into lateral femoral condyle
Lateral tuberosity of tibia

FIG. 8-D

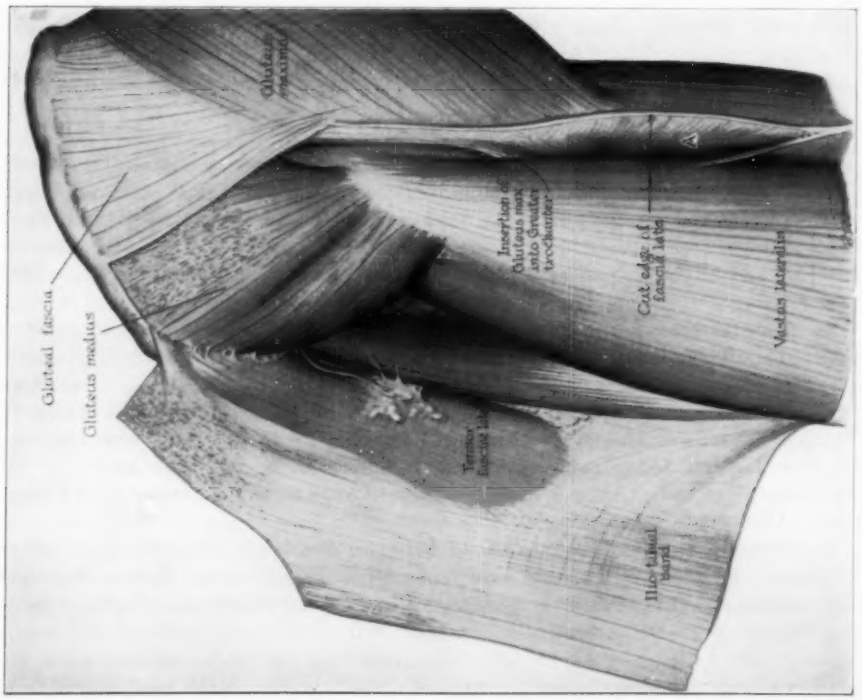
Gluteal fascia
Gluteus medius
Gluteus maximus
Insertion of Gluteus max into Gerdy's tubercle
Cut edge of fascia lata
Vastus lateralis
Ilio-tibial band

FIG. 8-C

thigh and reversed for examination of its deep surface, the insertion of the glutaeus maximus can be studied in detail. The glutaeus maximus inserts by its deep fibers into the posterior-inferior angle of the greater trochanter and into a tubercle known, in comparative anatomy, as the third trochanter. It represents the terminal area of extension of the lateral branch of the linea aspera. It also inserts into part of the iliotibial tract which is connected with the upper part of the lateral intermuscular septum, inserted into the linea aspera between the vastus lateralis and the biceps femoris. Examination of the distal half of the iliotibial tract transected in the middle portion of the thigh and reflected posteriorly for the study of the deep surface shows the following: The iliotibial tract is intimately connected with the intermuscular septum and the linea aspera from the greater trochanter to the supracondylar tubercle of the lateral condyle of the femur. The iliotibial tract is free of bone connections only between the upper portion of the femoral condyle and lateral tubercle of the tibia (the tubercle of Gerdy) (Figs. 8-C and 8-D). The iliotibial tract is tense in the cadaver, where obviously no muscle contraction exists. Transection of the tract in the middle portion of the thigh produces retraction of the anterior fibers not connected with the septum. Traction applied to the divided distal half of the band above the knee does not produce any motion of the knee joint. The reason for this is obvious: The insertion of the fascia lata and the iliotibial tract into the lateral muscular septum and into the linea aspera does not permit any longitudinal movement.

Examination of the iliotibial tract in the distal half of the thigh shows that it becomes thicker in the distal end. It is connected by curved fibers with the lateral border of the patella anteriorly and to the anterior fibers of the tendon of the biceps femoris posteriorly (Fig. 8-B). Thus, anatomically, the iliotibial tract represents a tense ligament stretched between the iliac crest and the lateral surface of the tibia intimately connected with the lateral septum and fixed longitudinally to the linea aspera. The tract is fused anteriorly with the tensor fasciae latae and posteriorly with the glutaeus maximus. It does not represent a tendon of the tensor fasciae latae or of the glutaeus maximus but is a thick conjoined ligament similar to Cooper's ligament in the groin extending to the upper portion of the lateral femoral condyle and to the lateral tibial tubercle (the tubercle of Gerdy) below the knee.

ELECTRICAL STIMULATION OF THE TENSOR FASCIAE LATAE AND GLUTAEUS MAXIMUS

Inasmuch as the tensor fasciae latae and glutaeus maximus are both intimately inserted into the iliotibial tract, stimulation of each muscle was done. To obtain a true picture of the results, the muscles were stimulated in patients who were under general anaesthesia for various surgical procedures. A faradic current was used which could be generally tolerated by any adult without anaesthesia. The results were similar to the findings of Duchenne.

The tensor fasciae latae produced strong retraction of the fascia lata, strong internal rotation of the thigh with flexion of the thigh forward and slightly outward.

In complete flexion, there is a lateral deviation of the thigh from the mid-line, amounting to about 5 degrees. If flexion is prevented, no deviation occurs. If flexion is allowed and the thigh is held in mid-line, practically without pressure or effort, no lateral deviation occurs. Therefore, the tensor fasciae latae cannot be considered an abductor.

Stimulation of the glutaeus maximus produced very strong extension of the thigh with very slight external rotation.

There was no transmission of action of these two muscles to the knee, regardless of the position of the knee or thigh during the stimulation. The fascia and the iliotibial tract appeared tensed anteriorly, if the tensor fasciae latae was stimulated, or posteriorly, if the glutaeus maximus was stimulated.

Stimulation of the tensor fasciae latae in patients who had the iliotibial tract resected below the greater trochanter showed the same results. Thus, electrical stimulation of these

muscles did not show that the iliotibial tract acted on the knee joint as a tendon for these muscles.

OBSERVATIONS IN SURGICAL PROCEDURES

In the lateral approach to the greater trochanter and to the lateral aspect of the shaft of the femur, it is necessary, in some instances for proper exposure, to divide the iliotibial tract and the fascia lata transversely. In normal extremities, the iliotibial tract, when exposed under general anaesthesia, presents a tense band regardless of the position of the thigh and knee. When the iliotibial tract is divided, the divided ends immediately retract distally and proximally, obviously not by muscle action. After operations, when the pain disappears (the division of the iliotibial tract having been done for purposes of exposure only), the patients are able to move the knee without impairment of function; they are also able to flex and internally rotate the thigh.

In cases in which the iliotibial tract and fascia lata were removed for purposes of obtaining autogenous fascia for transplantation elsewhere in the body, no perceptible changes of function were observed in the corresponding knees or thighs.

In extensive lateral approaches to the knee joint, it was noted that the iliotibial tract acted as an accessory anterolateral ligament of the knee preserving stability in instances in which the lateral collateral ligament was lost [14]. The part of the iliotibial tract between the supracondylar area of the lateral condyle of the femur and the lateral tibial tubercle (the tubercle of Gerdy) fulfilled this role.

In cases of resection of the head and upper end of the fibula, when the lateral collateral ligament and the tendon of insertion of the biceps femoris had to be sacrificed, preservation of the iliotibial tract helped to maintain stability of the knee joint.

The surgical procedures indicated that the iliotibial tract acted as a satisfactory stabilizer of the knee joint; they also showed that interruption of the iliotibial tract, and even excision of substantial parts of it, did not affect the function of the knee.

CLINICAL OBSERVATIONS

The iliotibial tract is considered by some observers to be a tendon of the tensor fasciae latae subjected to secondary contractures, when the muscle became permanently contracted [28]. The iliotibial tract could contract in poliomyelitis and simultaneously produce severe deformities involving the hip and knee joints [13]. The kinesiological investigations of Inman revealed the interrelation of the hip abductors and the tensor fasciae latae with the iliotibial tract as an abductor of the thigh. Steindler's description of the factors contributing to the normal and pathological motion indicated the complexity of the problems of interpretation in cases of paralyses and secondary contractures in diseases of the extremities and the trunk.

From the viewpoint of comparative anatomy, the iliotibial tract is an independent structure. The tensor fasciae latae muscle developed in animals without a simultaneous development of the iliotibial tract. In man, the tract is essential as a ligament connecting the ilium with the knee, but it is not a tendon. Contractions of the tensor fasciae latae do not transmit any force below the middle of the thigh except tension of the fascia lata. The iliotibial tract is, however, essential for erect posture, because its tension between the ilium and the upper portion of the lateral femoral condyle provides an additional stabilizing ligament for the knee joint. This additional ligament is the terminal part of the iliotibial tract between the upper portion of the lateral femoral condyle and lateral tubercle of the tibia (the tubercle of Gerdy). The contraction of the tensor fasciae latae is not transmitted to the lowermost portion of the iliotibial tract which spans the knee joint. This is proved by electrical stimulation of the tensor fasciae latae and by traction on the iliotibial tract in experiments on cadavera.

Electrical stimulation of the tensor fasciae latae directly observed on exposure of the

muscle in surgical procedures does not produce abduction of the thigh. It produces only flexion and medial rotation without any action on the knee joint. This confirms the findings of Duchenne.

Flexion contractures of the thigh are due to complex factors, as is well known. The tensor fasciae latae is a comparatively small muscle intimately associated with the surrounding muscles and, especially, with the glutaeus medius and glutaeus minimus. It may not be strong enough in itself to produce action on two separate joints. In paralyses of the glutaeus medius and glutaeus minimus, the tensor fasciae latae is almost invariably afflicted. In contracture of the glutaeus medius and glutaeus minimus, it is also involved. Abduction contractures of the hip joint are produced by the glutaeus medius and glutaeus minimus primarily. If the tensor fasciae latae is involved, its contracture in flexion is associated with the contracture of the two glutaei which produce abduction; its internal rotation contracture is enhanced by the glutaei. The tensor fasciae latae does not act as an abductor. In paralysis of the glutaeus medius and glutaeus minimus, regardless of the tensor fasciae latae, the dropping of the corresponding side of the pelvis is due to inaction of the glutaei, as proved by Duchenne in the so-called positive Trendelenburg sign. The tensor fasciae latae does not contribute directly in the production of this sign because it is not a stabilizer of the pelvis in abduction, but only in flexion.

Flexion contractures of the hip joint, frequently associated with abduction of the thigh and simultaneous flexion of the knee, are frequently due to contractures of the glutaeus minimus and anterior half of the glutaeus medius associated with contractures of the short head of the biceps. The tensor fasciae latae and the iliotibial tract may not be associated with this deformity.

CONCLUSIONS

The iliotibial tract, otherwise known as the iliotibial band, or the band of Maissiat, is a ligament connecting the ilium with the tibia. It is observed in its form in man and is associated with the erect posture. It is connected intimately with the tensor fasciae latae anteriorly and the glutaeus maximus posteriorly in the region below the greater trochanter. As a result of this study, the author feels that the femur is stabilized synergistically by the tensor fasciae latae and glutaeus maximus in standing and walking. The tensor fasciae latae pulls the tense band anteriorly in flexion; the glutaeus maximus shifts the band posteriorly in forced extension. The band is, however, held by the lateral intermuscular septum permitting a limited amount of anteroposterior motion. At the knee joint, the band acts as a stabilizing ligament between the lateral femoral condyle and the tibia in continuity with the proximal part of the band. This stabilizing ligament is attached to the upper portion of the lateral femoral condyle as a fixed point, and moves with the lateral tubercle of the tibia (the tubercle of Gerdy) forward in extension and backward in flexion of the knee joint.

The importance of the tensor fasciae latae and of the iliotibial tract has been, possibly, overestimated as a deforming factor in patients with paralyses and contractures.

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DISCUSSION

Dr. Ernest Gardner, Detroit, Michigan: I have three points to make with regard to Dr. Kaplan's paper. First, the iliotibial tract has a very strong attachment to the femur. If a thigh is divested of everything except glutaeus maximus, tensor fasciae latae, iliotibial tract, and lateral intermuscular septum, it is seen that these structures form a remarkably strong, musculoligamentous arrangement, notable for the strength of its femoral attachment. On anatomical and mechanical grounds it is unlikely that either of these muscles could transmit its action to the tibia.

Second, dissection and conjecture must be checked by experimental and clinical methods, such as Dr. Kaplan has done. Among his studies, he has used electrical stimulation of muscles. This is a valuable method, but because it shows what a muscle can do, but not necessarily what it does do, it should be checked by other methods. Our check is by electromyography, which allows one to record the electrical activity of muscle during normal movement and posture. This method in turn has defects that will be apparent from examination of the records.

When one stands in an easy standing position, few muscles in the lower limbs are active. The tensor fasciae latae shows little if any activity. It is most active during flexion and medial rotation of the hip; but it is also active during many other movements, especially abduction. It is a cardinal principal that in attempting to assess the function of a specific muscle, or to determine whether such a muscle is inactive during a particular movement, all joints except the one being studied must be stabilized and the influence of gravity minimized. Thus, in extending the leg, the tensor fasciae latae, and even the glutaeus medius, may seem to be active. If the thighs are stabilized so as to prevent hip movement during leg extension, then no activity is seen in tensor fasciae latae.

Electromyography confirms what Dr. Kaplan reported, that the action of the tensor fasciae latae is confined to the thigh and hip. It is mainly a flexor and medial rotator of the hip. I am not sure of its role in abduction. Although Dr. Kaplan found no abduction upon electrical stimulation of the tensor fasciae latae, electromyography reveals a very consistent response during abduction, one which has been reported by other observers. It may be that this represents a secondary activity, having a stabilizing influence during contraction of the glutaeus medius. This, I think, requires further study.

I doubt that the tensor fasciae latae acts synergistically with the glutaeus maximus in standing and walking. Most electromyographic studies indicate little if any activity of the glutaeus maximus during ordinary standing and walking. In other types of thigh or pelvis extension, however, the two muscles may well act synergistically.

Third, one other point must be considered. The function of the iliotibial tract is largely mechanical; however, it may also have a proprioceptive function. Superficial and deep nerves supply the tract, giving rise to pain and proprioceptive endings. The latter endings may well be stimulated during contraction of glutaeus maximus, tensor fasciae latae, biceps femoris, or underlying vastus lateralis, and may be a factor in reflex mechanisms during locomotion. There is no experimental evidence for this, however.

DR. KAPLAN (closing): There is not much to be added. My study of the anatomy and kinesiology of the tensor fasciae latae and the role of the iliotibial tract indicate that the role of the iliotibial tract is not fully understood.

In surgical division of the iliotibial tract for contracture, more than the tract alone is divided. In contractures producing abduction of the thigh, the cause cannot be assigned to one muscle or structure only, but to other muscles as well, of which the posterior third of the glutaeus medius in conjunction with the vastus lateralis is one of the important factors.

DISCUSSION

DUPUYTREN'S CONTRACTURE

(*Continued from page 792*)

fore it may be well to apply less radical forms of surgery in certain cases, namely localized fasciectomy or simple fasciotomy. The selection of treatment for the individual case requires good judgment.

DR. JOSEPH H. BOYES, LOS ANGELES, CALIFORNIA: How many have seen Dupuytren's contracture in the Negro or in the Oriental?

DR. H. W. MEYERDING, ROCHESTER, MINNESOTA: I have never operated on a Negro or an Oriental for Dupuytren's contracture. I was informed by a professor of surgery in India that Dupuytren's contracture is never seen in natives of that country.

DR. LARSEN (closing): In answer to Dr. Boyes' question, in the city of Detroit, which has a population of 1,910,000, and in the Greater Detroit area, with a population of 3,670,000, the Negro population is 375,000. We have found but two Negroes with Dupuytren's contracture, one man and one woman.

Osteotomy of the Cervical Spine

Report of a Case of Ankylosing Rheumatoid Spondylitis *

BY MARSHALL R. URIST, M.D., LOS ANGELES, CALIFORNIA

From the Department of Surgery, Division of Orthopaedics, University of California, Los Angeles

A safe procedure for operative correction of flexion deformities of the cervical spine is needed for patients with ankylosing spondylitis. Although osteotomy is generally accepted for treatment of deformities of the lumbar spine, for the cervical spine it is rarely employed and can result in failure to alter the deformity, in injury to the brachial plexus, or death of the patient. The operation presented here, performed on the cervical spine is an adaptation of the operation of Smith-Petersen, Larson, and Aufranc on the lumbar spine. It adds intertransverse process arthrodesis and suggests special safety measures.

CASE HISTORY

The patient is a forty-four-year-old housewife and mother of five children. Her present illness began in 1944 with stiffness and intermittent and remittent aching pains in the neck and upper portion of the back. In 1948, following the birth of her last child, she developed a flexion-rotation contracture that gradually increased in severity until it was not possible for her to raise her head to see straight ahead. In an attempt to overcome this difficulty, she had to rotate her head to the left. The head and neck became rigid in the fully flexed and rotated position and, for five years, she performed her household tasks in this position. At first, this deformity was not so much a handicap as it was grotesque. In 1951, a hysterectomy was performed to relieve her of the strain of rearing more children. The patient was a recluse but her mental status was surprisingly normal. She denied ever having had any injury to her neck. In August 1956, she complained of increasingly severe low-back pain and the flexion contracture of the neck increased until her chin was so tightly pressed against her chest that it was not possible for her to open her mouth and separate her teeth more than a few millimeters. Because she could not chew her food, she ate baby foods. While she was standing, with gravity acting to increase the deformity, her atrophied neck and back muscles felt tired and overstretched. She suffered from progressive exertional dyspnoea, and could only walk a short distance even if she stopped frequently to rest. In November 1956, the pain increased further in intensity and she was too weak to get out of bed. On the night of November 1, 1956, her family was awakened by the patient's screaming and weeping in her sleep. She dreamed that she could no longer breathe and she explained that life for her was no longer tolerable with this deformity. She appeared to be continuously dyspnoeic and complained of a feeling of constriction in her chest.

The patient had had the usual childhood diseases, and for the past five years had been under treatment for hypertensive cardiovascular renal disease with nocturia. She had had five pregnancies resulting in five children, all living and well. A review of systems was otherwise normal.

Laboratory Tests

A blood test revealed hemoglobin, 13.0 grams per 100 cubic centimeters; 4,200,000 red blood cells; and 7,300 white blood cells. The differential white blood cell count showed 60 per cent polymorphonuclear neutrophils; 7 per cent eosinophils; and 33 per cent lymphocytes. There were adequate platelets. The corrected sedimentation rate was 23 (modified Cutler). Urinalysis was within normal limits. An electrocardiogram showed a tracing that bordered on the normal, but that suggested early ventricular hypertrophy.

Physical Examination

The patient, a pale white woman, had a spine completely rigid and deformed by disease. The neck was flexed to 110 degrees and the head was rotated 45 degrees to the left. The curvature of the thoracic spine was increased to the point of marked kyphosis. The curve of the lumbar spine was reversed from an anterior to a posterior curve. This produced a symmetrical round-back flexion deformity of the thoracolumbar area, and also contributed to the reduction of her height. There was no motion of any other segments of the spinal column in any direction. The skin was shiny, red, and tender where it was stretched tightly over

* These investigations were aided in part by grants from the Josiah Macy, Jr. Foundation, the Ayerst Laboratories, Inc., the Lee S. Mytinger Foundation, and The Easter Seal Foundation for Crippled Children and Adults.

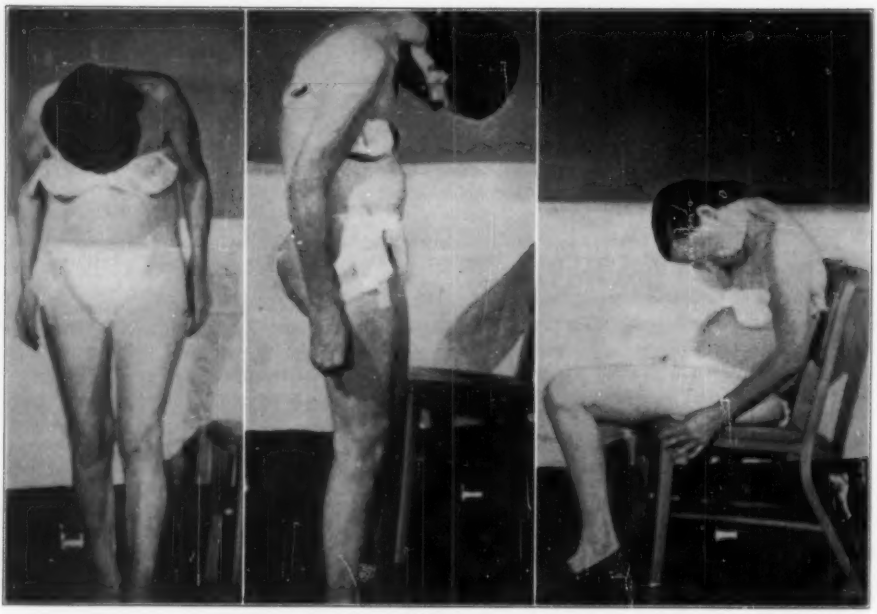

FIG. 1

These preoperative photographs of the patient show the mandible pressed against the chest.

FIG. 2

Photograph showing the maximum distance that the mandible could be raised from the chest wall by the examiner's hand seen on the left, three months before the operation. The spinous processes of the sixth and seventh cervical vertebrae appear in profile.

the spinous processes in the lower cervical and upper thoracic regions. There was a small decubitus ulcer in the sacral region. The eyes were deviated upward and to the right to compensate for the flexed position, and levorotation enabled the patient to see what was ahead of her. The neuromuscular examination was essentially negative except for atrophy of the sternocleidomastoid muscles. The function of the cranial nerves was not remarkable; motor and sensory functions were also normal and all of the reflexes were present (Figs. 1 and 2).

She was slightly fatigued by prolonged standing or sitting, and complained of vague discomfort in her

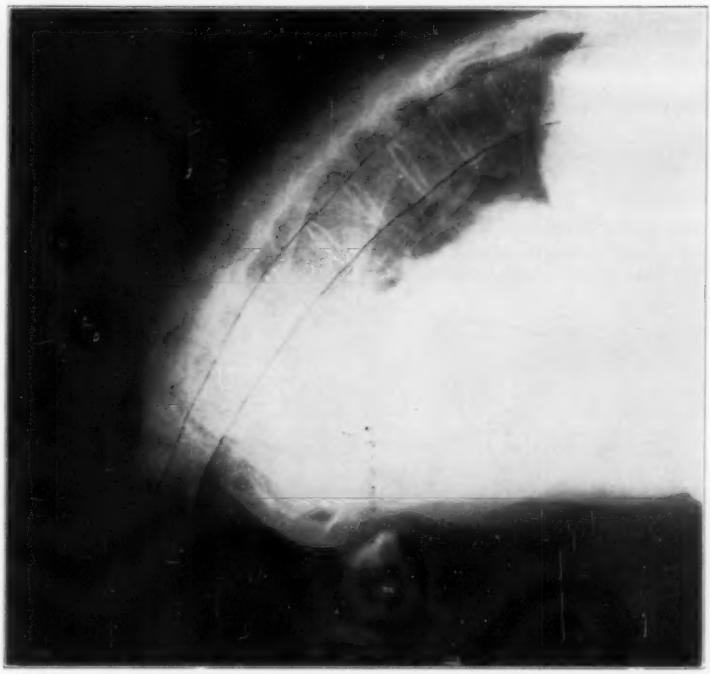

Fig. 3-B

Figs. 3-A and 3-B: Roentgenograms made preoperatively, showing the patient's head in the middle of the chest in the anteroposterior view, and the mandible pressed against the clavicle in the lateral view (retouched to show the spinal column).

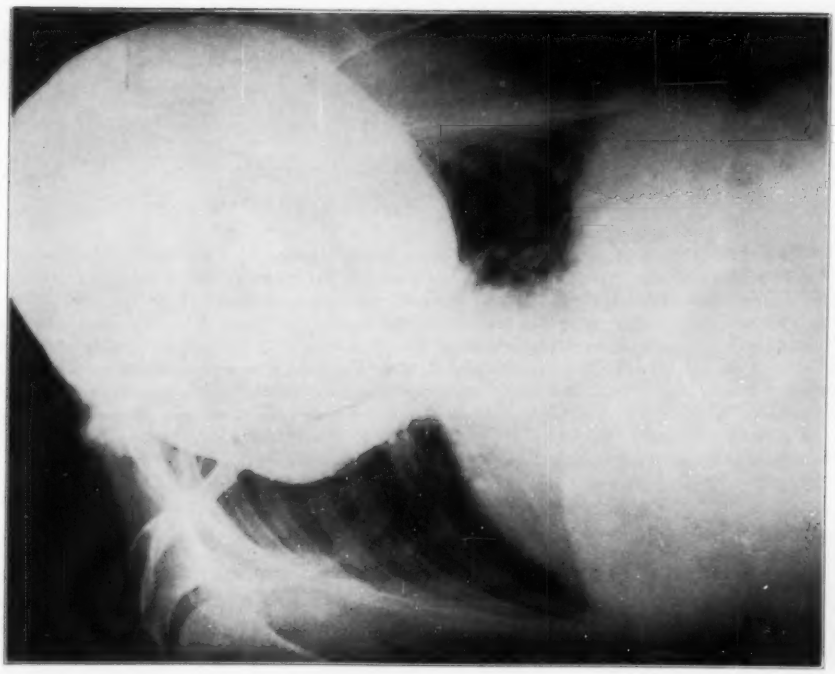

Fig. 3-A

chest and generalized pain in the spine when she was supine. Her blood pressure was 195 systolic, 106 diastolic. Her pulse rate was irregular, 120 per minute, and her respiration was regular, twenty-two per minute. Her vital capacity was 30 per cent of normal for her height and weight. There was no excursion of the chest or movement of the ribs with respiration; breathing was transmitted across both the thoracic and pelvic diaphragm in the expiratory phase. The lungs were clear except for bilateral basal rales. The heart was enlarged to the left and there was sinus tachycardia. The sounds were booming, and A_2 was equal to P_2 in intensity. There was a Grade I apical murmur. The abdomen was protuberant and soft.

Roentgenographic Examination

The bone structure was slightly atrophied but all of the joint spaces in the upper and lower extremities were relatively normal. The disease was almost exclusively in the axial skeleton. The entire spine was ankylosed by abnormal bone formation across the annulus fibrosis and the intervertebral joints. All of the

FIG. 4

Sketch showing the position of the patient on the operating table.

intervertebral-disc spaces were diminished in thickness and surrounded by bone on all sides. The cervical spine was hyperflexed so that it was impossible to visualize it in the anteroposterior view. In the lateral view the cervical area showed the typical bamboo spine with severe osteoporosis but no fractures. All of the cervical intervertebral joints were fixed in flexion, and the apex of the flexion deformity was at the level of the seventh cervical vertebra. The roentgenogram of the chest made with the patient standing was obscured by the view of the patient's skull on the middle of the film (Fig. 3-A). The costovertebral articulations were solidly ankylosed by new bone. The thoracolumbar spine and the sacro-iliac joints were also ossified in a flexed position. The involvement of the lumbar spine in this disease process was less advanced than that in the cervical or thoracic spine. The sacro-iliac joints, however, were obliterated by new bone. A diagnosis of von Bechterew's disease or descending form of ankylosing rheumatoid spondylitis was made.

SURGICAL TREATMENT

Anatomical Considerations

The level between the seventh cervical and the first thoracic vertebra was the location of the apex of the flexion contracture in this case. This interspace is more receptive to surgical treatment than any other level of the cervical region. The spinal canal is relatively wide and the cervical cord and eighth cervical-nerve root have good flexibility in this area.

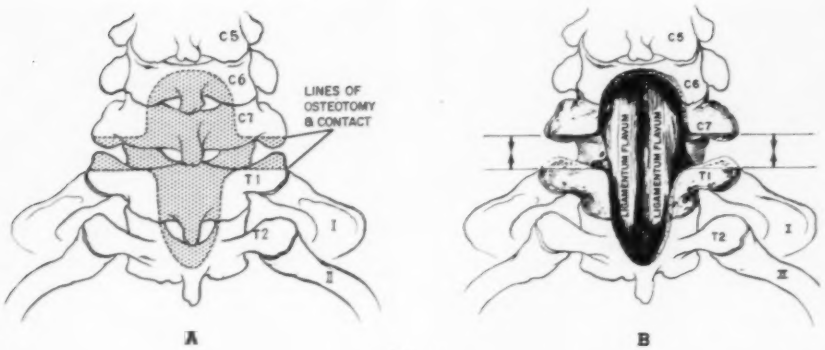

FIG. 5

These sketches show *A*, the close anatomical relationship of the transverse processes of the seventh cervical and first thoracic vertebrae; and *B*, the line of osteotomy in the posterior view of the spine following wedge resection of the spinous processes, laminae, pedicles, and transverse processes, and exposure of the intact unossified layers of the ligamentum flavum.

The radicular distribution of the sensory fibers of the eighth cervical nerve for pain, touch, and thermal sensibility is limited very closely to the ulnar aspect of the lower portion of the arm, and hand, and the fourth and fifth digits. For motor function, the eighth cervical-nerve root supplies muscles that receive concomitant innervation from the seventh cervical and first thoracic roots. Any weakness caused by injury to the eighth cervical-nerve root is consistent with good function of the hand. Weakness of ulnar deviation of the hand, weakness of grip, and weakness of abduction of the little finger are reliable indications of interference with the eighth cervical-nerve root. More important than preservation of the eighth cervical-nerve root, however, is protection of the spinal cord against excessive angulation or sudden distortion of the bone walls of the cervical spine.

The passage of the vertebral artery through the transverse foramina of the cervical vertebrae presents a unique anatomical situation, but fortunately the vertebral artery and veins usually pass in front of the transverse process of the seventh cervical vertebra and enter the transverse foramen of the sixth cervical vertebra. The transverse foramen

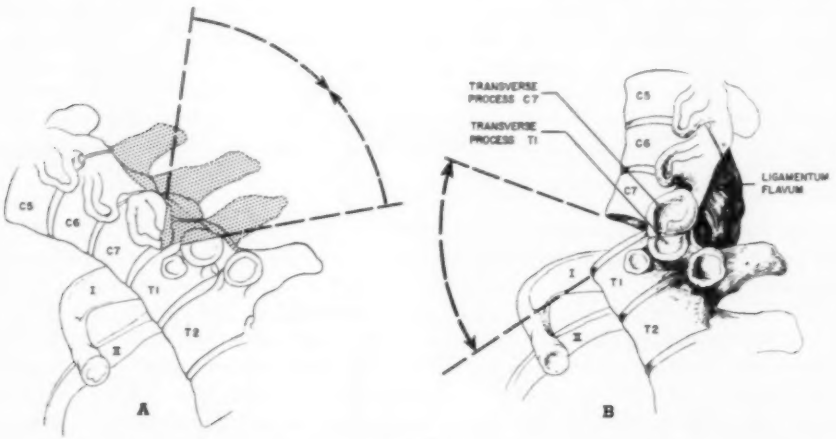

FIG. 6

These sketches show *A*, the line of osteotomy in the lateral view before correction of the deformity; and *B*, the contact between the osteotomized transverse processes and the opening of a 64-degree angle in the intervertebral-disc space in the lateral view of the seventh cervical and first thoracic vertebrae.

FIG. 7-A

FIG. 7-B

Fig. 7-A: Anatomical preparation of the skeleton showing the posterior aspect of the cervicothoracic junction with the transverse first thoracic vertebra overlapping and almost touching. The dotted lines indicate the line of section of the osteotomy.

Fig. 7-B: Lateral view of the preparation shown in Fig. 7-A. The ribs have been removed on the left, to show the position of the transverse process of the seventh cervical vertebra anterior to the transverse process of the first thoracic vertebra. The dotted lines indicate the line of section of the wedge resection.

of the seventh cervical vertebra is small and sometimes may have the artery and vein passing through it on both sides or only the artery passing through it on the left side. However, the position of these blood vessels above the level of the first thoracic vertebra protects them against serious harm during osteotomy of the spine. The danger of cerebral ischaemia from reduction of blood flow through the basilar artery from kinking or constriction of one vertebral artery is slight, but if the constriction is bilateral, the risk is considerable. The acute flexed position of the neck in this patient made intratracheal intubation through the mouth very difficult and local rather than general anaesthesia was selected. Preparations were made for tracheotomy in the event that it was necessary to have a direct airway. The patient was preoperatively given atropine (0.25 milligram) and 100 milligrams of demerol. The operation was performed with subcutaneous infiltration of 2 per cent xylocaine followed by a brief period of nitrous oxide and oxygen inhalation.

Surgical Procedure

The patient was placed in a sitting position on a folded operating table (Fig. 4). The Craig attachments were arranged for a head rest. Mayo stands were used for arm rests for intravenous infusions of fluids or blood. Through a mid-line incision, extending from the fifth cervical vertebra to the second thoracic vertebra, the spinous processes and laminae were exposed bilaterally. The wound was held open with two large Beckman self-retaining retractors. The cervical muscles were detached from the spinal column by blunt dissection with Hibbs sponges and periosteal elevators. The spaces between the laminae were overgrown with abnormal bone formation, but the shapes of the spinous processes were convenient distinguishing landmarks of the segments of the spinal column. The sixth cervical vertebra was identified by its bifid spinous process, and the seventh cervical vertebra was identified by its single spinous process. The first thoracic vertebra was identified by the articulations of the first rib (ankylosed in this case) on both sides.

FIG. 8-A

FIG. 8-B

Roentgenograms of the cervical spine eleven months after surgery. The anteroposterior view shows contact and fusion between the transverse processes of the seventh cervical and first thoracic vertebrae (Fig. 8-A). The lateral view shows the opening of the 64-degree angle in the intervertebral-disc space, spontaneous fusion of the vertebral bodies in the area of the joints of Luschka, the elongated intervertebral canal following removal of the pedicle, and the lamina and spinous process of the seventh cervical vertebra.

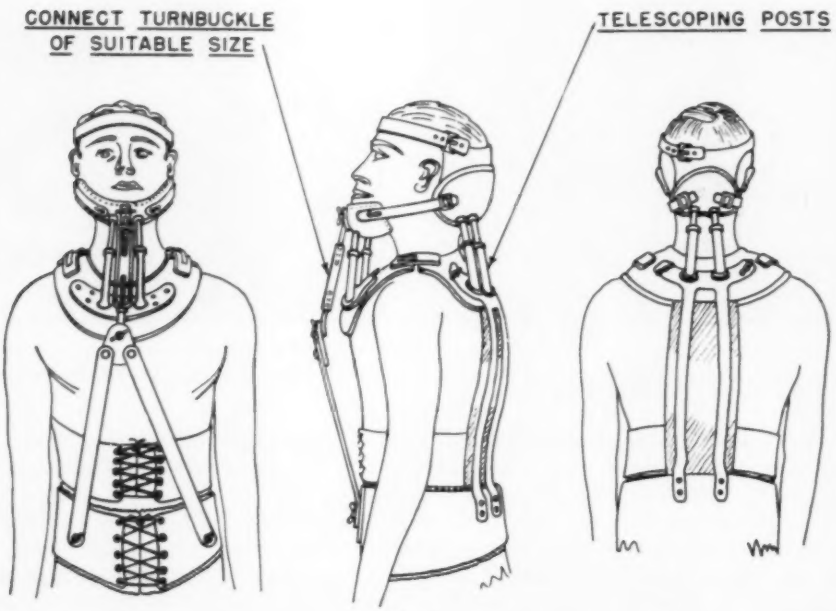

FIG. 9

These sketches show the turnbuckle brace which was used to obtain slow correction and full extension of the spine during the first two weeks after the operation.

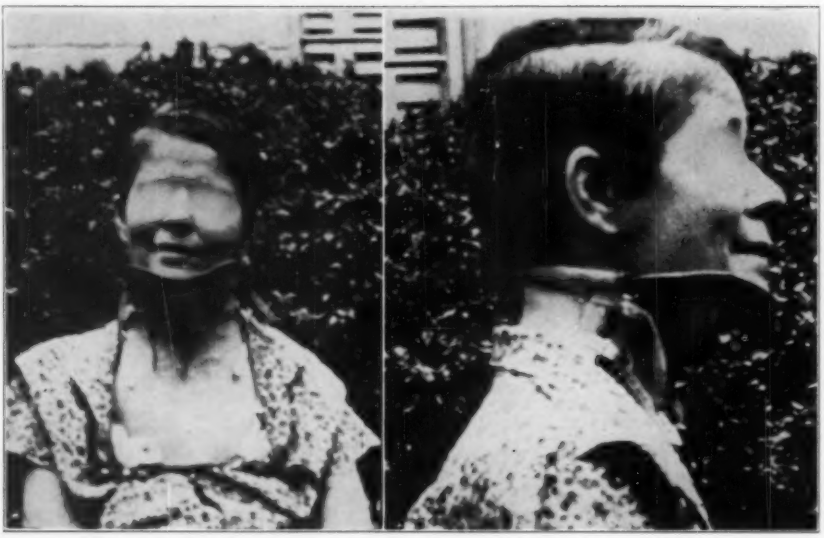

FIG. 10

Photographs showing the patient in a molded leather cervical collar four months after the operation.

FIG. 11

Photographs showing the patient six months after the operation and the profound change in her appearance and in her psychological outlook upon life.

The spinous processes, laminae, and most of the pedicles of the seventh cervical vertebra were all removed with small rongeurs. The osseous tissue was peeled out of the attachments to soft tissue. Small blunt periosteal elevators and cottonoid sponges were placed between the bone and soft parts for dissection and protection. The ligamentum flavum was partly soft and fibrous rather than solidly ossified as roentgenograms are often erroneously interpreted. Instead, it consisted of two layers: an unossified deep layer attached to the dura mater and a superficial ossified layer continuous with the capsular ligaments, intervertebral ligaments, and periosteum. By the removal of bone tissue only, there remained an irregular layer of soft tissue all around the resected laminae and pedicles

to bind the vertebrae to each other. The laminectomy was extended lateralward on both sides to include the lower edges of the transverse processes of the seventh cervical vertebra and the upper edges of the transverse processes of the first thoracic vertebra. A gap approximately 1.5 centimeters was thus produced in the posterior portion of the spine at the cervicothoracic interspace.

For decompression and additional space that might be needed later when the spinal canal was angulated, the laminae and spinous processes were removed from the first thoracic vertebra, the sixth cervical vertebra, and part of the fifth cervical vertebra. Here also the pathologically softened bone was separated from the ligaments or the periosteum and from the unossified parts of the ligamentum flavum.

As soon as the resection of bone was finished, the patient was anaesthetized briefly with nitrous oxide and oxygen. With the soft-tissue coverings of the spinal cord and eighth cervical-nerve roots completely freed of surrounding hard tissue and clearly open to inspection, the first assistant was given the task of elevating the chin and attaching a chin rest to the table to hold the head and neck in a new position. He lifted the chin slowly and steadily until he felt and heard a soft snap like the sound of breaking a branch from a green tree. The patient was not conscious but she responded to the painful stimulus with a muffled cry inside of the anaesthesia mask.

A roentgenographic examination made in the operating theater showed that a rupture of the ossified annulus fibrosis had occurred anteriorly at the level of the seventh cervical intervertebral space. As soon as the patient was fully awake and capable of cooperating with the anaesthetist who tested the sensory perception and reflexes in both upper extremities, the chin was elevated slowly until it was two inches away from the chest. (It is important to note whether the soft tissues covering the spinal cord slide upward and downward inside the spinal canal and are relaxed and relieved of tension or their previously stretched position by this procedure.) There was no need for opening the dura mater to untether the spinal cord at its dentate ligaments. The soft tissues and muscles beside the spinal cord were equally relaxed and the wound was easy to close without tension. Bone grafts were not implanted, although they could have been placed outside of the osteotomy line of the transverse processes. It seemed wiser to omit this step to avoid the danger of migration of loose fragments of bone toward the nerve roots (Figs. 5 through 8).

The patient was fully awake within a few minutes and able to cooperate while she was transferred from the head rest to a spinal brace designed with a turnbuckle to elevate and extend the cervical spine (Fig. 9). The patient was observed in the recovery room where, for a period of six hours, she was comfortable with the aid of small doses of demerol, fifty milligrams every three hours.

CONVALESCENCE

The patient was returned to her room where a tracheotomy set was held in readiness at all times; fortunately, the need to use it did not arise. Every day, over a period of one week, the chin was elevated a few millimeters at a time with the aid of the turnbuckle. At every stage, several times a day, the patient's reflexes and sensory perceptions were tested for injury to the spinal cord or nerve roots. There was no pain until the eighth day when she complained of a burning sensation in the fourth and fifth digits of the left hand. The biceps and triceps reflexes were equal and active. There was weakness of the grip and loss of abduction of the little finger. At this time the cervical spine was actually hyperextended and the turnbuckle was unthreaded to lower the chin at least two centimeters. This relieved the pain but dysaesthesia followed and persisted for approximately three weeks after the operation. These symptoms and signs occurred on the left side only and all disappeared within six months. The head had been ankylosed in the rotated position at the articulation between the atlas and the axis. When the deformity was corrected with the turnbuckle set in one plane, some derotation occurred at the osteotomy site.

This probably produced slight pressure on the eighth cervical-nerve root. Although it was never a serious complication, it possibly could have been avoided by setting the universal joint on the chin piece to retain the original position of rotation of the head. The functional result, however, might not have been as satisfying as it now is to this woman and her family (Figs. 10 and 11).

The deformity was finally corrected with the intervertebral space opened to an angle of 64 degrees. Two weeks after the operation the sutures were removed and the patient was transferred from the turnbuckle brace to a plaster Minerva jacket. Twelve weeks after the operation, the plaster was removed and replaced by a molded leather cervical-spine brace. The patient was advised to wear a cervical collar for protection indefinitely when she is riding in an automobile or is likely to be in crowded places.

DISCUSSION

That osteotomy of the cervical spine was feasible and could be a safe operation, was suggested by end-result studies of several cases of fracture of the cervical spine recorded in the literature on ankylosing spondylitis. Bergmann presented a review and added four cases in 1949. In treating the fractures, he was able to correct some of the flexion deformity of the neck at the levels of the fifth, sixth, and seventh cervical vertebrae in three of his four patients. Healing was so rapid that union was observed in roentgenograms as early as six weeks. Rogers recently reviewed the end results of a large series of patients with injuries to all parts of the cervical spine. He included one patient with a fracture through the level of the fourth intervertebral disc in an ankylosed cervical spine. Re-fusion occurred spontaneously in an improved position. In ten weeks, in addition to healing of the fracture, the intervertebral-disc space was completely replaced by new bone. Such cases may be regarded as accidental closed osteotomies of the spine.

At least four open osteotomies of the cervical spine have now been reported in the literature. In 1953, Mason and associates reported one and, in 1954, Herbert reported three that he had performed during the seven-year period from 1947 to 1954. The method used by Mason and associates included surgical transection of the body and of the calcified intervertebral disc of the first thoracic vertebra as well as presumably of most of the posterior elements of the seventh cervical and first thoracic vertebrae; the patient disappeared and an end-result examination was not possible. Herbert elected to osteotomize only the posterior elements of the spine at the level of the fifth and sixth cervical vertebrae. He observed that root compression was the principal danger and found temporary weakness of the deltoideus muscle in one patient. He did not osteotomize the intervertebral-disc space anteriorly. He did not see any danger in folding or occluding the vertebral artery. He did not implant bone grafts and he correctly relied on the disease to fuse the spine spontaneously. The results in two patients were good. One patient died due to loss of control of extension apparatus used for postoperative treatment and correction of the deformity. Professor Herbert visited the author in Los Angeles on July 1, 1957, and kindly reviewed his fifty-four cases of osteotomy of the spine. He has now dispensed with the use of traction. He approved of the anatomical reasons and safety features in electing to do the operation at the level of the seventh cervical vertebra in preference to the level of the fifth cervical vertebra.

Osteotomy of the spine has been performed on three additional patients, but the accounts have not been reported in the literature. They came to the author's attention through personal communications with two anonymous surgeons in other parts of the United States. In two of these patients, serious complications occurred from unwise or incorrect application of traction and difficulties in controlling it. Irrespective of the obvious dangers of moving the cervical spine, one surgeon manipulated a severely flexed ankylosed spine, and was fortunate enough to obtain a good correction by manual osteoclasis under nitrous oxide anaesthesia without complications.

SUMMARY

Correction of a severe flexion deformity and slight hyperextension of the cervical spine was produced safely at the level between the seventh cervical vertebra and first thoracic vertebra in a woman, forty-four years old. The osteotomy was performed posteriorly under local anaesthesia; the ossified annulus fibrosis was ruptured anteriorly by manipulation under nitrous oxide and oxygen anaesthesia while the spinal canal was exposed and protected by the surgeon. Full correction of the deformity was attempted only under controlled conditions after the patient was fully awake and after the spine was securely immobilized in a full spinal brace equipped with a jury-mast and a turnbuckle to raise the chin. The turnbuckle was unthreaded slowly and the cervical spine was extended in stages while the patient was closely observed and frequently examined to test her sensory perceptions, reflexes, and muscle power.

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Femoral-Head Phlebography

A Method of Predicting Viability

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The prognosis of intra-articular fracture of the femoral neck depends on vascular damage to the proximal fragment, the head, which is mainly intra-articular. The displacement of the fragments results in interruption of all intrinsic-vessel anastomoses within the femoral neck so that the only remaining blood supply to the head is through the ligamentum teres and uncertain synovial bridges. In the literature there are many studies of the vascular anatomy of the upper end of the femur, the results of which are mainly in agree-

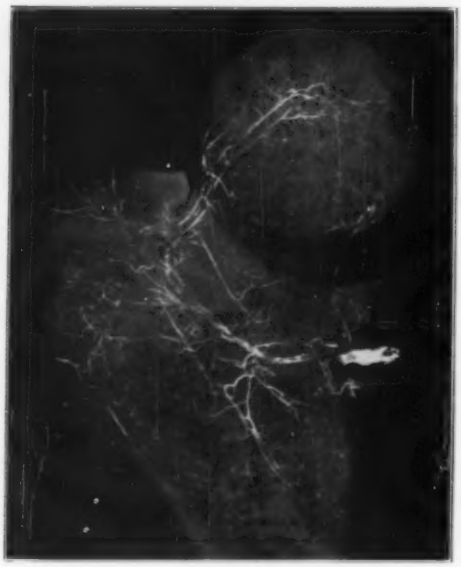

Fig. 1

Fig. 2

Fig. 1: General view of the intra-osseous circulation in the upper end of the femur. Cinnabar was injected into the medial circumflex femoral artery of a large specimen. The medial circumflex artery is seen across the base of the neck, the important superior retinacular vessels on the upper edge, and the inferior retinacular vessels on the lower edge of the neck.

Fig. 2: Photomicrograph (× 20) of the inferior retinaculum showing arteries filled with black India ink and unfilled veins. The corticalis of the neck is seen at the lower right.

ment and complement each other[7,8,11,12,15,16,20,21,23,24]. The most important vessel for the femoral head is the medial femoral circumflex artery running along the posterior side of the base of the neck (Fig. 1). The branches to the head course within the joint cavity in synovial reflections of the capsule (the retinacula) at the superior and the inferior edges of the neck. Of the two retinacula the one on the superior edge contains the largest and most important vessels. The arterial branches run in close contact with the venous branches in these retinacula[10,20] (Fig. 2). The ligamentum teres even in old people most commonly contains larger or smaller vessels which undoubtedly contribute to the nutrition of the head[7,8,20,21,23]. In cases of trochanteric fracture, the circumflex vessel and all of its

branches are located on the proximal fragment (Fig. 3-A). In all fractures of the true neck, however, the same branches have to cross the open fracture gap (Fig. 3-B). Neck fractures without displacement have a greater chance of having intact synovial-vessel branches than do displaced neck fractures. In the latter there is a considerable risk that the superior retinacular vessels, on the upper edge of the neck, will be stretched or torn [7, 11, 20], but even the inferior vessels may be damaged and the ligamentum teres may be avascular.

Several attempts have been made to develop a method for the early diagnosis of avascularity. Both isotopic [1, 2, 22] and angiographic [14, 18] techniques have been employed. However no definite results have been reported. The chief difficulty in arteriography is that those vessels which are of interest, the foveal and the retinacular branches, are so small that it is not easy to distinguish them. Intra-osseous venography of the head fragment

FIG. 3-A

FIG. 3-B

Fig. 3-A: Postmortem arteriogram of a specimen with a trochanteric fracture. The medial circumflex femoral artery is situated on the proximal fragment. On the upper edge of the neck the superior retinacular arteries are seen.

Fig. 3-B: Postmortem arteriogram of a specimen with a neck fracture. The medial circumflex femoral artery is situated on the distal fragment. The vessel supply by the retinacular vessels seems to be slight.

yields better results [9, 10]. Veins, even the small retinacular branches, can be indicated on roentgenograms more simply and surely than can the corresponding arteries. The method is based on the fact that a contrast medium injected into the cancellous bone of the femoral head immediately fills the veins. (There are many essays published about intra-osseous venographic techniques in general [3, 4, 6, 13, 19].) Since the vessel supply of the head is characterized by parallel arteries and veins [9, 10, 20], it may be concluded from positive findings of typical head veins that the corresponding arteries exist. The veins are more fragile than the arteries. Therefore part of the avascular necrosis is possibly due to vein damage. This method, then, ought to be more definite than the arteriographic technique, because of its superior ability in indicating vessel damage. The method has the advantage of being simple; it is performed at operation with ordinary portable roentgenographic apparatus.

TECHNIQUE

A stainless-steel cannula with an obturator was used (Fig. 4). The cannula tapers gradually toward the tip, the outer diameter diminishing from five to 3.2 millimeters. It is ten centimeters long and has an inner diameter of 2.3 millimeters. The obturator is about

one centimeter longer than the cannula. The broad end of the cannula is provided with threads which fit into a handle used for insertion and withdrawal. The obturator fits into a hole one centimeter deep in the handle. This permits the cannula with the obturator protruding the correct distance to be driven into the femoral head.

The venographic examination should be performed no earlier than the third day after the fracture. Before that time one can assume that the vessels at the fracture site have not thrombosed and that the contrast medium will readily leak out when it is injected. The fracture is first reduced with the patient on an operating table. It is necessary that two portable x-ray machines be in position throughout the entire procedure.

The cannula must first be carefully inserted into the trochanteric fragment under roentgenographic control and then hammered a previously calculated number of centi-

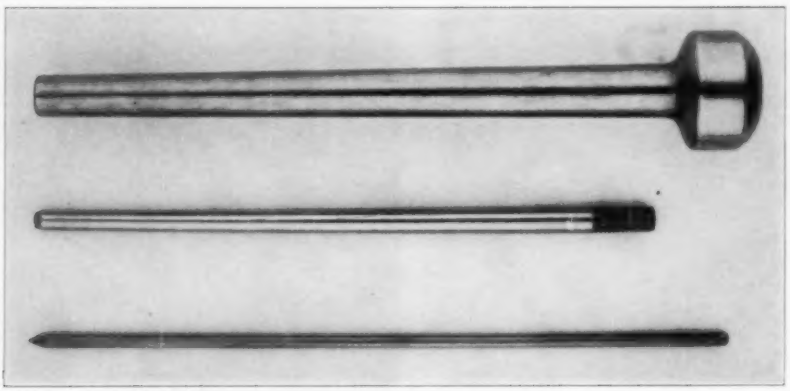

FIG. 4

The cannula used by the author (center). It is provided with an obturator (bottom) and a handle (top).

meters into the head. The head fragment itself must not be penetrated in more than one place because the injected contrast medium will leak out through the wrong canal. The cannula is driven at nearly a right angle to the lateral surface of the femur high up on the trochanteric surface. When the cannula is in its proper place, centrally and far into the head fragment (the tip at least two centimeters into the fragment), the contrast medium is injected. Two milliliters of 35 to 50 per cent umbradil is injected at a rate of about one milliliter every four seconds. The first anteroposterior roentgenogram is made immediately following the injection and a lateral film is made immediately thereafter. Two minutes after the first, another anteroposterior roentgenogram is made. Before the withdrawal of the cannula one to two milliliters of physiological saline solution is injected in order to wash out the remaining contrast fluid.

The injection of two milliliters of contrast material is sufficient for the purpose of venographic examination, because the existing veins are filled at the very beginning of the injection. A larger amount of contrast material (for example, five to six milliliters which was used in the beginning of this study) yields more distinct venous patterns but the use of such relatively large quantities of hypertonic contrast solution in cancellous bone tissue already in a state of stasis might be damaging. When there are no veins intact the greater part of the injected two milliliters of opaque material leaves the head fragment and is visible in the fracture and the joint. If a greater amount is then injected more contrast material accumulates in the joint but yet no veins will be visible.

The resistance to injection generally is surprisingly small — about the same as that to an intravenous injection. In some cases, however, there is great resistance. This seems

to depend mainly on the position of the tip of the cannula with respect to the trabeculae. If the cannula be driven in an additional millimeter or two, injection can then be performed without difficulty.

Types of Venography

The filling of the veins with contrast medium occurs instantaneously. There is a distinction between positive and negative venograms. Positive venograms are those in which the veins from the head are filled with contrast medium. These veins belong partly to the external iliac venous system (the retinacular veins, medial femoral circumflex vein, femoral, and external iliac veins), partly to the internal iliac venous system (foveal vein in the ligamentum teres, the acetabular, obturator, and internal iliac veins). In circumflex

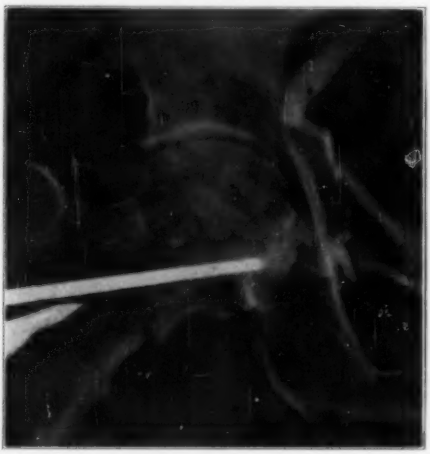

FIG. 5

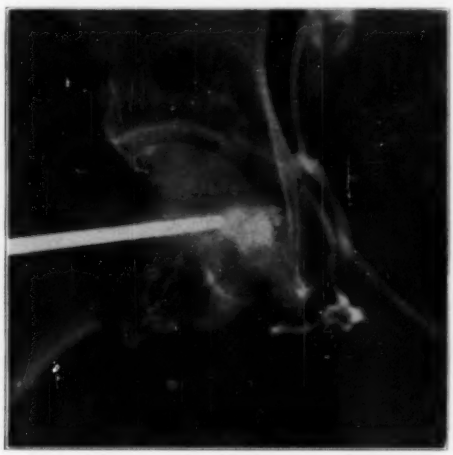

FIG. 6

Fig. 5: A positive venogram of the ligamentum teres type. The foveal vein, the obturator, and internal iliac veins are seen in this ninety-year-old man with a displaced femoral-neck fracture. Two milliliters of 50 per cent umbradil was injected in fifteen seconds.

Fig. 6: A positive venogram of the ligamentum teres plus circumflex type. The foveal, obturator, and internal iliac veins, and below, the inferior retinacular vein are seen in a woman, aged sixty-one years, with a displaced femoral-neck fracture. Three milliliters of 50 per cent umbradil was injected in ten seconds.

venograms, the former venous system is filled and in ligamentum teres venograms, the latter (Fig. 5). In certain cases both these systems are filled at the same time (Figs. 6 and 7). In negative venograms (Fig. 8) there are no veins visible and the contrast medium has instead flowed out into the fracture or has remained in the cancellous bone of the head. If the cannula has been placed correctly (far into the central part of the head and with no extra holes created) such a negative venogram indicates avascularity.

In addition there were some inconclusive venograms due to technical failures. These uncertain venograms (seventeen cases in my series) were partly atypical positive venograms and partly false negative venograms. Those positive venograms in which the separate retinacular veins could not be seen were placed in the former category. In certain non-displaced or only slightly displaced fractures the contrast material seemed to have crossed the fracture into the neck and from there entered the veins without filling the typical femoral-head veins (retinacular or ligamentum teres veins). These were evaluated as venograms of the neck fragment but not as venograms of the head (and therefore without predicting value). The false negative venograms were those in which the cannula had not been placed correctly. At first such negative venograms made when the cannula had been inserted less than one centimeter from the fracture without contrast-material loading of the cancellous tissue were evaluated as false negative. Further, venograms with the

FIG. 7

FIG. 8

Fig. 7: A positive venogram of the circumflex plus ligamentum teres type. The foveal, obturator, and internal iliac veins are seen. The inferior retinacular vein is below. This is a man aged seventy-five years, with a displaced neck fracture. Two milliliters of 50 per cent umbradil was injected in eighteen seconds.

Fig. 8: Negative venogram indicating avascularity. The cannula has a good position in the femoral-head fragment. No veins are visible and the contrast medium is partly retained in the cancellous bone of the head, partly at the fracture site. This is a man aged seventy-eight years with a displaced neck fracture. Two milliliters of umbradil was injected in twelve seconds.

Fig. 9: Venogram of a femur with a trochanteric fracture in a woman eighty-seven years old. The contrast medium is seen in the intrinsic veins within the bone of the neck. The medial circumflex femoral vein is across the base of the neck medial to the fracture. Three milliliters of 50 per cent umbradil was injected in eleven seconds.

FIG. 9

occurrence of double canals in the head or perforation of the joint cartilage also had to be interpreted as false negative. In all of these instances the injected contrast medium had no opportunity to come into contact with veins which might have been intact; instead it leaked out into the joint or fracture.

Venography in Different Types of Fractures

In trochanteric fractures (twelve cases) the residual vascularity was good. The important medial femoral circumflex vein was situated on the proximal fragment and the intrinsic veins within the neck were intact (Fig. 9). Sixteen patients with non-displaced neck fractures (valgus fractures) were examined of whom only two had negative venograms. The vascularity with these valgus fractures is better, particularly in regard to the circumflex veins, than that with the displaced fractures.

The displaced neck fractures, so-called varus fractures, have the greatest interest as the subject for a method of predicting viability since it is among these that most of the poor results occur. Of eighty-two patients with displaced neck fractures examined, fifty-two had positive venograms. In nineteen of these a circumflex type of venogram was done, some in combination with a ligamentum teres type of venogram. In thirty-three the ligamentum teres type of venogram only was done (Table I). The other thirteen had negative venograms indicating avascularity. (In addition there were seventeen patients with atypical venous patterns and false negative venograms due to technical failures.) The ligamentum teres type of picture occurred mainly among the oldest patients (seventy-six years and older). In the positive circumflex venogram, in displaced fractures, usually only the inferior retinacular veins were filled with contrast material; occasionally the superior retinacular veins also appeared (three cases).

Since the superior retinacular veins are of considerable size one expects them to be visible more often. Therefore, when they are absent in the venograms, they have probably been damaged. This is also quite natural considering the type of displacement (varus displacement with diastasis of the upper part of the fracture in addition to antecurvature of the neck). Because of the occurring diastasis there is a considerable risk of the superior

TABLE I

TYPES OF VENOGRAPHY IN DISPLACED NECK FRACTURES

Age of Patients (*Years*)	No.	Positive Venograms			Total Positive Venograms	Negative Venograms	Uncertain Venograms
		Circumflex	Circumflex Plus Teres	Teres			
Under 75	43	10	6	14	30	8	5
Over 76	39	1	2	19	22	5	12
Total	82	11	8	33	52	13	17

retinacular vessels on the upper edge of the neck becoming stretched or torn. The inferior retinacular vessels, however, running postero-inferiorly in the very hinge of the displacement, have a more protected course, and therefore more often are undamaged.

FOLLOW-UP INVESTIGATION

The follow-up period in the cases presented here is at least one year—in some it was longer. This space of time is not sufficient to allow the detection of late manifestations but it is enough for detecting the avascular manifestations occurring in the fracture region itself. The fact that a few additional cases of collapse of the upper edge of the head may occur after a longer period of observation does not alter the conclusions with respect to the mechanism of development of avascular necrosis, which I have drawn from the material presented. The following discussion is limited to the follow-up of patients with displaced neck fractures (varus fractures). Forty-three patients examined venographically were followed. Of these, thirty-one had positive venograms and twelve had negative venograms. Among the thirty-one positive there were ten obvious instances of avascular necrosis. In the twelve patients with negative venograms there were early signs of necrosis. There are however two different types of avascular manifestations occurring with the positive and the negative venograms. The latter indicate total avascularity and the necrosis manifests itself in the fracture region either by development of non-union or by continued resorption of the metaphyseal (or distal) region of the head but with gradual healing of the fracture [5]. The head fragment in the latter cases has a characteristic mushroom appearance (Figs. 10-A through 10-D). Secondary to the resorption, an increased penetration of the nail occurs eventually with penetration of the joint cartilage. In some cases the nail may slide outward. If instead, a pseudarthrosis or secondary coxa vara occurs, further resorption may be checked or retarded because of inadequate contact with intact bone tissue resulting from the filling of the fracture site by fibrous tissue.

FIG. 10-A

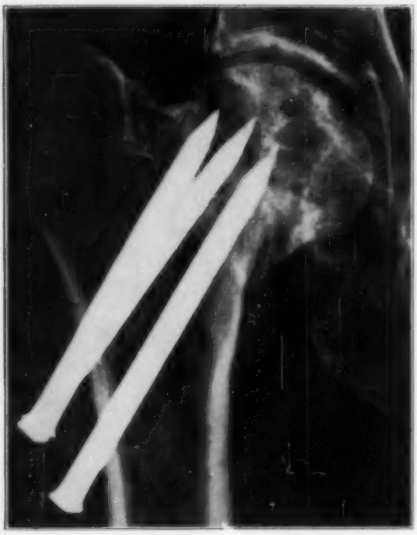

FIG. 10-B

Figs. 10-A through 10-D: Roentgenograms showing avascular necrosis with resorption of the distal portion of the femoral head in a woman sixty-six years old who had a displaced fracture of the femoral neck. The venogram was negative.

Fig. 10-A: Anteroposterior roentgenogram made immediately after nailing.

Fig. 10-B: Anteroposterior roentgenogram made seventeen months after nailing. The neck has bored into the fragile head and the nails are slipping.

Of the twelve patients with negative venograms pseudarthrosis developed in five, distal resorption of the head with mushroom configuration in four, and coxa vara with the nails ploughing out through the head of the femur, in two. The remaining patient had collapse of the superior contour of the head.

The avascular manifestations occurring in ten of thirty-one patients with positive venograms had another appearance. Because there was only a relative insufficiency of the blood supply due mainly to the damage of the important superior retinacular vessels, the fracture usually healed. Secondarily, however, there occurred a collapse of the superior portion of the head, because the remaining vessel supply from the inferior retinaculum or ligamentum teres was insufficient for the nutrition of the entire fragment. The most remote or superior part of the head is the area most likely to suffer. Of the ten patients with necrotic manifestations six had such a collapse of the superior part of the head. Only one case of pseudarthrosis occurred (in a patient with a ligamentum teres type of venogram). In addition there occurred one case of delayed union (in a patient with a circumflex type of venogram) and one case of the nail's ploughing out through the head (in a patient with a ligamentum teres type of venogram). In one patient a relative density and mottled appearance was the dominating manifestation of avascularity. In the remaining twenty-one patients healing progressed without trouble.

SUMMARY

The femoral head is supplied by the medial femoral circumflex artery and the obturator artery, and the supply is chiefly characterized by the prolonged intra-articular course of the vessels, partly in folds of the synovial membrane and partly in the ligamentum teres. The vessel branches to the head are comprised of parallel arteries and veins. Trochanteric fractures course lateral to the medial circumflex vessel, as distinguished from the fractures of the true neck, all of which are medial to this vessel. In the former type of frac-

FIG. 10-C
Lateral roentgenogram made immediately after nailing.

FIG. 10-D
Lateral roentgenogram made seventeen months after nailing.

ture, therefore, this vessel with all its branches remains on the central fragment, while in neck fractures its branches must bridge the fracture in remnants of the synovial membrane.

The method described for the performance of intra-osseous phlebography of the femoral head in neck fractures makes it possible to study the residual vascularity of the head fragment in different types of fractures. The types of venograms in neck fractures are positive in which the circumflex and ligamentum teres veins are filled with contrast material, and negative, in which no venous filling occurs. The negative venogram indicates avascularity but a good position of the cannula is required to show this.

Non-displaced fractures differ from displaced fractures mainly in that in the former the remaining circumflex vascularization is considerably better. There are fewer cases of this type of vascularization among patients with displaced fractures and in these the circumflex vascularization is usually limited to the inferior retinacular vessels. In these displaced fractures there is instead a ligamentum teres type of vascularization to a large extent, especially in older patients.

Forty-three patients with displaced neck fractures examined venographically were followed. There were twelve negative venograms which all showed early signs of necrosis. There were thirty-one patients with positive venograms of whom ten eventually showed manifestation of necrosis but a different type than the necrosis found after negative venograms. The method herein described makes possible the early definitive diagnosis of avascularity in at least half of the patients in whom it will later occur.

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The Significance of Metallic Transfer in the Corrosion of Orthopaedic Screws *†

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Previous work has shown that it is, practically speaking, almost impossible to handle a screw with a screwdriver without some metal from the driver being left adhering to the screw [7]. An account of the general principles involved has been published [1], as have general surveys of the significance of metallic transfer in orthopaedic surgery together with accounts of physical experiments [2, 3, 4, 5, 6, 7, 14].

CORROSION OF IMPLANTED METAL

Corrosion of metal is a complicated phenomenon involving many factors [9]. Corrosion in an electrolytic fluid, such as the body-tissue fluid, consists essentially in the passage of ions into solution at one part of the metal, and out of solution at another part, accompanied by the transfer of electrons. These parts are the anode and cathode of a simple electrical battery and may exist on one piece of metal or on separate pieces. Certain metals and alloys with suitable strength for orthopaedic purposes are more resistant to corrosion than others under the special conditions existing in the human body [10, 16]. Of these, the stainless steel known as AISI 316 and the cobalt-chromium-molybdenum alloy known as Vitallium are in common use.

FACTORS ENCOURAGING CORROSION IN THE BODY

The factors which may interfere with the inherent resistance to corrosion and which may cause failure of these metals are of great importance to the orthopaedic surgeon. Some of them will be discussed briefly.

Mixed Metals

The insertion into the body of dissimilar metals, or metals of different composition, with the setting up of a battery between the separate metallic parts, is an obvious source of corrosion [9]. Even differences in the composition of stainless steels made by different manufacturers or at different times in the same mill may be important in this respect. Dissimilarity of metallurgical condition, including hardness and grain size, may also lead to corrosion by giving areas of differing potential and thus forming the poles of a battery on the same piece of metal or between adjacent parts, such as between one screw and another.

Fretting Corrosion

Minimal movements between one metal surface and another may cause fretting corrosion at the points of contact of the metals [17]. This process acts by grinding away the surface of the metal and repeatedly damaging the oxide layers and allows the electrolytes in the surrounding fluid to attack the alloy.

Differential Aeration

A current will pass between areas of metal having differing oxygen tensions in their

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† Material for this study was supplied by Zimmer Manufacturing Co., Warsaw, Indiana, and Austenal, Inc., New York, N. Y.

environment [9]. This process is called differential aeration and its application to the body is obvious. Different areas of the bone and soft tissue near implanted material may have widely varying blood flows and therefore different oxygen supplies. Muscle or bone death may have resulted from trauma of fracture or operation. This exposes two parts of the implanted material to completely different oxygen tensions and is especially true if there is tissue or bone death adjacent to part of the implanted material as is seen in aseptic necrosis of cortical bone. The lowest concentration of oxygen is found where one piece of metal is firmly clamped to another as at screw-to-plate interfaces and other such places.

Electrolyte Gradient

Areas in contact with fluids having different electrolyte concentrations will also react and a current pass between the two areas, leading to corrosion. Such differences may be found if part of the implanted material is in contact with dead tissue, a hematoma, or oedematous tissues.

Surface Damage

It is also well known that surface damage may render a metal susceptible to corrosion by removing the protective oxide layer or oxide sludge on its surfaces, exposing the bare metal to electrolysis. Such damage may occur at any time before, during, or after the operation.

Elastic and Plastic Stress

Areas of metal stressed by bending or locally deforming forces may come to be in a changed metallurgical condition and will then react with undamaged metal.

Surface Imperfections

Manufacturers of both cast (cobalt-chromium-molybdenum) and machined (AISI 316) materials take great pains to remove all surface metallic débris from their products. Undoubtedly this is difficult and especially so with AISI 316 screws. Electrolytic polishing and manual removal of metallic burrs do much to render these screws safe. Some manufacturers take more trouble with this process than others. All the screws used in this study were inspected not only for burrs and débris, but also for consistency of size and shape. A report on such an analysis of over 500 orthopaedic screws is in preparation.

Metallic Transfer

It has been known for some time that tissue reaction around implanted material was maximal around the part which had been handled with a tool. It has recently been shown by radioactive-isotopic techniques that any contact between metal surfaces is accompanied by the transfer of minute metallic particles from one surface to the other [2]. This process is explained by the fact that no metallic surface is truly flat as is seen when viewed with the high powers of the optical or electron microscope. Thus when one surface touches another, the only actual contact is over the very small area of the apexes of their irregularities. These touching points sustain great pressures and weld together. When the surfaces are pulled apart the welds remain firm and the metal breaks in the work-hardened zone adjacent to the weld. Thus after the insertion of a screw with a screwdriver for instance, the metal of the screw slot is seeded with many small pieces of the driver. This also happens between wrench and bolt or nut, between rotating drill and plate, if allowed to touch, and between saw blade and drill and bone [5, 6, 7, 8].

The dangers of metallic transfer are obvious for the inert corrosion-resistant metal of the implanted material has been contaminated with the metal of the tool which may have a very different composition and be far from inert. Mixed metals have been inserted. A

TABLE I

DETAILS OF SPECIFICATION OF METALS USED
Percentage by Weight

Element	FMB (18-8 SMo)	AISI 316-317	Martensitic	AISI 420	Vitallium	Tool Steel
Carbon	0.07	0.08 maximum	0.19	0.30–0.35	Trace	0.50
Chromium	18.0	17.0–20.0	13.60	12.0–14.0	30.0	
Nickel	8.0	10.0–14.0	0.34			
Manganese	0.50	2.0 maximum	0.20	0.47 (1.0 maximum)	Trace	0.40
Silicon	0.30	0.75 maximum	0.24	1.0 maximum	Trace	1.00
Molybdenum	2.75	4.0			3.0	0.50
Phosphorus		0.03 maximum		0.04 maximum		
Sulphur		0.03 maximum		0.03 maximum		
Cobalt					65.	
Iron	Balance	Balance	Balance	Balance	.5–1.0	Balance

reaction may start around the many small batteries which have been created; the implanted metal thus corrodes.

FACTORS INFLUENCING METALLIC TRANSFER

Similar and Dissimilar Metals

Transfer is greatest between like metals and least between unlike metals [4]. It may be thought that this is harmless since the transferred particles have the same composition as that of the implanted metal. These particles are, however, in a different metallurgical condition which may be just as dangerous, as they may have been hardened by pressure and plastically deformed during the transfer. Corrosion can be expected to occur as readily as if the two metals were dissimilar.

The transfer between dissimilar metals, although less in total amount, is very significant from the point of view of initiating corrosion, for the dissimilarity of composition in an electrolytic medium may produce strong electrolysis and thus corrosion [7].

Hardness of the Tool and Implanted Metal

Metallic transfer is greatest between metals in like metallurgical conditions [4]. The harder screwdrivers should be expected to give less transfer regardless of their composition, but they will cause greater damage to the surface of the implant by plastic deformation and may do harm by setting up corrosion cells in the deformed areas.

The problem is then one of avoiding metallic transfer from the screwdriver to the screw without at the same time increasing damage to the screw slot.

EXPERIMENTAL METHOD

An experiment was designed to determine the effect of varying amounts of metallic transfer and of plastic deformation on the corrosion of orthopaedic screws buried in the back muscles of rabbits for three months. Such a bed provides a constant temperature, constant pH after the first acid tide of healing, a balanced electrolytic-fluid bath, and a constant level of oxygen partial pressure.

The amount of corrosion of each type of screw was estimated by weighing before and after insertion into the animal. The tissue around each screw was examined histologically and spectrographically for evidence of cellular reaction and for the presence of metallic salts derived from the metal. Weighed batches of screws were also buried in animals after being handled with screwdrivers of various types and alloys, and the screws and tissues were similarly examined at the end of the experiment. Other batches of screws were

TABLE II

WEIGHT CHANGES OF AISI 316 SCREWS IN MANUAL EXPERIMENTS

Screwdriver	Before Handling (*Milligrams*)	After Handling (*Milligrams*)	Net Change	Per cent Change
AISI 420 stainless steel	832.9	833.0	+.1	+.0120
	800.0	800.3	+.3	+.0375
	826.5	826.7	+.2	+.0242
	804.4	804.6	+.2	+.0248
	825.2	825.3	+.1	+.0121
	843.6	843.8	+.2	+.0237
	Average gain: +0.0224 gram per 100 grams Standard deviation: ±0.0095			
Low-alloy tool steel	834.2	834.3	+.1	+.0119
	754.3	754.3	0	0
	808.8	809.1	+.3	+.0370
	847.3	847.5	+.2	+.0236
	834.7	834.9	+.2	+.0239
	775.3	775.4	+.1	+.0128
	Average gain: +0.0182 gram per 100 grams Standard deviation: ±0.0128			
AISI 316 stainless steel	827.8	827.9	+.1	+.0120
	770.8	771.0	+.2	+.0256
	839.2	839.3	+.1	+.0119
	773.2	773.4	+.2	+.0258
	840.1	840.3	+.2	+.0238
	833.8	833.9	+.1	+.0119
	Average gain: +0.0185 gram per 100 grams Standard deviation: ±0.0072			
18-8 SMo steel	729.6	729.6	0	0
	764.8	764.9	+.1	+.013
	770.7	770.7	0	0
	780.9	781.0	+.1	+.0120
	735.5	735.6	+.1	+.0135
	760.3	760.3	0	0
	Average gain: +0.0064 gram per 100 grams Standard deviation: ±0.0070			
Martensitic stainless steel	749.2	749.3	+.1	+.0132
	758.4	758.2	−.2	−.0263
	753.7	753.7	0	0
	767.2	767.1	−.1	−.0130
	730.1	730.2	+.1	+.0136
	754.3	754.1	−.2	−.0278
	Average loss: −0.0067 gram per 100 grams Standard deviation: ±0.0070			

weighed, then handled with screwdrivers of the various types, and then reweighed to detect any changes due solely to metal transfer or abrasion of the screw slot by the driver.

The insertion of the screws into the back muscles of rabbits provided a reasonably equally oxygenated surface all around each screw. Differential aeration was thus at a

TABLE III

WEIGHT CHANGES IN COBALT-CHROMIUM-MOLYBDENUM SCREWS IN MANUAL EXPERIMENTS

Screwdriver	Before Handling (*Milligrams*)	After Handling (*Milligrams*)	Net Change	Per cent Change
AISI 316 stainless steel	464.2	464.3	+.1	+.0213
	482.1	482.0	−.1	−.0207
	480.1	480.2	+.1	+.0208
	461.8	461.9	+.1	+.0216
	462.9	463.0	+.1	+.0216
	459.8	459.9	+.1	+.0217
	Average gain: +0.0144 gram per 100 grams Standard deviation: ±0.0172			
AISI 420 stainless steel	473.1	473.0	−.1	−.0211
	463.4	463.4	0	0
	482.3	482.3	0	0
	461.7	461.7	0	0
	479.5	479.5	0	0
	470.1	470.2	+.1	+.0212
	Average change: 0.00 Standard deviation: ±0.0133			
Low-alloy tool steel	465.3	465.4	+.1	+.0214
	468.9	469.0	+.1	+.0213
	486.1	486.2	+.1	+.0205
	460.7	460.8	+.1	+.0216
	478.9	479.0	+.1	+.0208
	472.3	472.4	+.1	+.0211
	Average gain: +0.0211 gram per 100 grams Standard deviation: ±0.0004			

minimum and there was also no electrolyte gradient. Each screw, being free from contact with other metal or bone, was expected to remain free of fretting corrosion and of the known dangers of mixed metals.

When a pilot hole is drilled into a bone to receive a screw, the bone is heavily contaminated by metal transfer from the drill [6]. This cause of corrosion was avoided by inserting the screws into a muscle bed. In addition, the screw could be recovered for examination at the end of the experiment without unscrewing it forcibly. Any change in weight due to damage during unscrewing was thus eliminated. Further, it is much easier to detect adverse tissue reaction in soft tissue than it is in bone, as shown by Collins' difficulty in detecting bone reaction to metal.

The only factors then left unaccounted for were metallic transfer from the screwdrivers, deformation of the screw slots by the driver, and the inherent degree of corrosion resistance of the alloy of which the screw is made. The experimental standard for the latter was provided by the buried control batches of unhandled screws. The other two factors were varied by comparing the effects of six types of screwdrivers on screws made of two different alloys.

MATERIALS AND SPECIFICATIONS

The compositions of the various alloys are shown in Table I. The following screws were obtained: (1) seventy-eight 18-8 SMo (AISI 316) stainless-steel screws of the Sherman type (made in the United States) both single-slotted and cross-slotted, of Rockwell-C

TABLE IV

WEIGHT CHANGES IN AISI 316 AND COBALT-CHROMIUM-MOLYBDENUM SCREWS IN *IN VIVO* EXPERIMENTS

	Before Implanting (*Milligrams*)	After Implanting (*Milligrams*)	Net Change	Per cent Change
A				
AISI 316 screws unhandled	779.1	778.6	−.5	−.0641
	827.7	827.6	−.1	−.0120
	791.4	791.1	−.3	−.0391
	793.6	793.6	0	0
	799.2	798.9	−.3	−.0375
	776.8	776.4	−.4	−.0514
	Average loss: −0.034 gram per 100 grams			
	Standard deviation: ±0.0240			
B				
AISI 316 screws AISI 420 driver	876.6	876.1	−.5	−.0568
	836.1	835.3	−.8	−.0956
	882.2	882.1	−.1	−.0113
	887.2	887.0	−.2	−.0236
	875.1	874.8	−.3	−.0342
	872.4	872.0	−.4	−.0458
	Average loss: −0.0446 gram per 100 grams			
	Standard deviation: ±0.0297			
C				
AISI 316 screws Tool steel single-slotted driver	808.0	807.4	− .6	−.0742
	817.6	816.9	− .7	−.0856
	812.1	811.4	− .7	−.0861
	802.6	801.3	−1.3	−.1619
	795.3	794.7	− .6	−.0754
	820.1	819.5	− .6	−.0731
	Average loss: −0.0927 gram per 100 grams			
	Standard deviation: ±0.0344			
D				
AISI 316 cross-slotted screws Tool steel cross-slotted driver	792.0	791.1	−.9	−.1132
	796.3	795.6	−.7	−.0879
	819.8	819.2	−.6	−.0731
	792.1	791.7	−.4	−.0505
	799.1	798.8	−.3	−.0375
	799.8	799.5	−.3	−.0350
	Average loss: −0.0662 gram per 100 grams			
	Standard deviation: ±0.0309			
E				
AISI 316 screws AISI 316 single-slotted driver	797.1	796.0	−1.1	−.1380
	869.1	868.5	− .6	−.0690
	870.2	869.7	− .5	−.0574
	785.4	784.7	− .7	−.0891
	876.4	875.6	− .8	−.0912
	811.8	810.8	−1.0	−.1231
	Average loss: −0.0946 gram per 100 grams			
	Standard deviation: ±0.0309			
F				
AISI 316 cross-slotted screws AISI 316 cross-slotted driver	822.7	822.3	−.4	−.0486
	844.9	844.2	−.7	−.0828
	804.9	804.3	−.6	−.0733
	823.2	822.5	−.7	−.0850
	824.5	824.0	−.5	−.0606
	819.0	818.8	−.2	−.0244
	Average loss: −0.0624 gram per 100 grams			
	Standard deviation: ±0.0232			

TABLE IV *(Continued)*

	Before Implanting *(Milligrams)*	After Implanting *(Milligrams)*	Net Change	Per cent Change
G				
	883.6	883.8	+.2	+.0226
AISI 316 screws	869.9	869.9	0	0
Martensitic steel	872.0	871.6	−.4	−.0457
driver	871.6	871.5	−.1	−.0114
	844.3	844.1	−.2	−.0236
	861.3	860.9	−.4	−.0464
	Average loss: −0.0174 gram per 100 grams			
	Standard deviation: ±0.0269			
H				
	875.9	875.4	−.5	−.0570
AISI 316 screws	867.8	867.5	−.3	−.0345
18-8 SMo driver	860.8	860.5	−.3	−.0348
	886.6	886.4	−.2	−.0225
	871.6	871.0	−.6	−.0688
	886.0	885.7	−.3	−.0338
	Average loss: 0.0419 gram per 100 grams			
	Standard deviation: ±0.0173			
I				
	811.0	811.1	+.1	+.0123
Cobalt-chromium-	895.4	896.0	+.6	+.0669
molybdenum	992.3	993.1	+.8	+.0806
untouched	490.8	491.0	+.2	+.0408
	472.6	472.8	+.2	+.0423
	488.9	488.9	0	0
	Average gain: +0.0405 gram per 100 grams			
	Standard deviation: ±0.0308			
J				
	853.5	853.7	+.2	+.0234
Cobalt-chromium-	876.3	877.1	+.8	+.0912
molybdenum screws	806.8	807.1	+.3	+.0371
AISI 420 driver	464.9	464.9	0	0
	478.5	478.4	−.1	−.0208
	465.1	465.0	−.1	−.0215
	Average gain: +0.0182 gram per 100 grams			
	Standard deviation: ±0.0308			
K				
	771.2	770.7	−.5	−.0648
Cobalt-chromium-	760.3	659.8	−.5	−.0657
molybdenum screws	749.3	749.2	−.1	−.0133
Tool steel driver	748.3	748.0	−.3	−.0400
	807.5	807.4	−.1	−.0123
	749.5	749.4	−.1	−.0133
	Average loss: −0.0349 gram per 100 grams			
	Standard deviation: ±0.0257			
L				
	816.5	815.9	−.6	−.0734
Cobalt-chromium-	754.2	754.1	−.1	−.0135
molybdenum screws	815.7	815.3	−.4	−.0490
AISI 316 driver	761.1	760.8	−.3	−.0393
	809.3	809.2	−.1	−.0123
	821.2	820.8	−.4	−.0487
	Average loss: −0.0394 gram per 100 grams			
	Standard deviation: ±0.0234			

TABLE V

STATISTICAL SIGNIFICANCE OF WEIGHT CHANGES OF AISI 316 SCREWS IN MANUAL EXPERIMENTS USING VARIOUS SCREWDRIVERS (TABLE II)

Screwdriver	AISI 420 Stainless Steel	Low-Alloy Tool Steel	AISI 316 Stainless Steel	18-8 SMo Driver	Martensitic Stainless-Steel Driver
AISI 420 stainless steel					
Low-alloy tool steel	†				
AISI 316 stainless steel	†	†			
18-8 SMo	**	†	*		
Martensitic stainless steel	**	*	*	†	

† = Difference between means is not statistically significant ($P > 0.05$).
* = Difference between means is statistically significant ($0.05 > P > 0.01$).
** = Difference between means is statistically significant ($0.01 > P > 0.001$).

hardness 30 to 35, which had been electropolished; and (2) forty-two cobalt-chromium-molybdenum (Vitallium) Sherman-type screws, single-slotted and coarse-threaded and of Rockwell-C hardness 28 to 32.

The following screwdrivers were obtained: (1) 18-8 SMo stainless steel (AISI 316) both for single-slotted and cross-slotted screws, of Rockwell-C hardness 30 to 35, chromium plated to a depth of 0.0002 inch, the plating having a Rockwell-C hardness of 62 to 64; (2) AISI 420 stainless-steel driver for both types of screw and of Rockwell-C hardness 49 to 51 and chromium plated as described; (3) low-alloy tool steel driver for both types of screw, having a Rockwell-C hardness of 57 to 58, and chromium plated as described; (4) Lane-type screwdriver of FMB 18-8 SMo stainless steel of Rockwell-C hardness 32, electropolished, passivated, and not plated; and (5) a similar driver of martensitic stainless steel of hardness Rockwell-C 34, non-passivated, and not plated.

EXPERIMENTAL DETAILS

Preparation of Screws

Every screw was carefully inspected for imperfections under a watchmaker's eyeglass. All metallic burrs and adherent débris were removed. Handled with rubber-tipped forceps, the screws were scrubbed in strong detergent, rinsed in turn in water, absolute alcohol, and ether, and then air-dried. Each screw was then weighed on a Sartorius-Werke balance to the nearest 0.1 milligram, two weighings by each of two technicians being taken each time. The sensitivity of this balance in differential weighing in the selected range of sensitivity is given as .05 milligram. It was felt that taking weights only as far as the nearest 0.1 milligram reduced experimental error. Six of each group of control or unhandled screws, both 316 and cobalt-chromium-molybdenum, were then sealed in separate numbered packets and autoclaved for the *in vivo* experiments. Batches of six inspected and cleaned screws of each alloy were then handled with screwdrivers. The screw was held in the rubber-gloved fingers of the left hand and six screwing movements were made in its slot with the appropriate screwdriver held in the right hand. Effort was made to make the force used in each action uniform. Naturally the force used and the amounts of spontaneous slip of the driver in the screw slot were much less than they are in operations. These screws were then reweighed to determine if the handling with metal drivers pro-

TABLE VI

STATISTICAL SIGNIFICANCE OF WEIGHT CHANGES IN COBALT-CHROMIUM-MOLYBDENUM SCREWS IN MANUAL EXPERIMENTS (TABLE III)

Screwdriver	AISI 316 Stainless Steel	AISI 420 Stainless Steel	Low-Alloy Tool Steel
AISI 316 stainless steel			
AISI 420 stainless steel	†		
Low-alloy tool steel	†	**	

† = Difference between means is not statistically significant ($P > 0.05$).
** = Difference between means is statistically significant ($0.01 > P > 0.001$).

duced any detectable change in weight. A second group of similarly handled screws was then autoclaved in separate paper packets for the *in vivo* experiment.

In Vivo Experiment

The control and the handled batches of screws were then inserted into animals, each screw being placed in its own bed in the sacrospinali of healthy albino five-pound rabbits. Full aseptic technique was used and no wound infection occurred. Three months later the animals were slaughtered and the screws removed within a block of muscle tissue. These blocks were placed in formol saline for about two hours and then the screws were carefully removed to avoid surface damage to the metal. Each screw was cleaned in detergent, rinsed in water, absolute alcohol, then in ether, and finally air-dried. Reweighing was then performed to the nearest 0.1 milligram, the mean of two weighings being taken.

The tissue blocks were put through the routine paraffin imbeddings, sectionings, and staining with hematoxlyin and eosin. A second section from each block was stained for iron with 4 per cent hydrochloric acid and 4 per cent potassium ferrocyanide to produce the Prussian-blue reaction to iron, and then counterstained with carmalum. The blocks were then sent for spectrographic analysis for trace metals.

RESULTS

Weight Changes in the Manual Experiment

The weights in milligrams of the AISI 316 stainless-steel and the cobalt-chromium-molybdenum (Co-Cr-Mo) screws before and after handling with screwdrivers are shown in Tables II and III, respectively. Each weight is the mean of two weighings brought to

TABLE VII

MEANS AND STANDARD DEVIATIONS OF WEIGHT CHANGES IN *IN VIVO* EXPERIMENTS (TABLE IV)

Type of Screw	Control	AISI 420	Screwdriver: Tool Steel Single-Slotted	Tool Steel Cross-Slotted	AISI 316 Single-Slotted	AISI 316 Cross-Slotted	Martensitic Stainless Steel	18-8 SMo (FMB)
AISI 316	A	B	C	D	E	F	G	H
Mean	−0.034	−0.0446	−0.0927	−0.0662	−0.0946	−0.0624	−0.0174	−0.0419
Standard deviation	±0.0240	±0.0297	±0.0344	±0.0309	±0.0309	±0.0232	±0.0269	±0.0173
Co-Cr-Mo	I	J	K	*	L	*	*	*
Mean	+0.0405	+0.0182	−0.0349		−0.0394			
Standard deviation	±0.0308	±0.0308	±0.0257		±0.0234			

* = No experiment made.

TABLE VIII

STATISTICAL ANALYSIS OF WEIGHT CHANGES IN AISI 316 AND COBALT-CHROMIUM-MOLYBDENUM SCREWS IN *IN VIVO* EXPERIMENTS (TABLE IV) (t VALUES)

	A	B	C	D	E	F	G	H	I	J	K	L
A AISI 316 screws unhandled		0.68	3.43**	2.02	3.79**	2.08	1.13	0.65	4.78***	‡	‡	‡
B AISI 316 screws AISI 420 driver			2.59*	1.24	2.86*	1.16	1.66	1.19	‡	2.95*	‡	‡
C AISI 316 screws Tool steel single-slotted driver				1.44	0.10	1.79	4.25**	3.23**	‡	‡	3.30**	‡
D AISI 316 cross-slotted screws Tool steel cross-slotted driver					1.59	0.24	2.92*	1.68	‡	‡	‡	‡
E AISI 316 screws AISI 316 single-slotted driver						2.04	4.62***	3.64**	‡	‡	‡	3.49**
F AISI 316 cross-slotted screws AISI 316 cross-slotted driver							3.10*	1.14	‡	‡	‡	‡
G AISI 316 screws Martensitic steel driver								1.88	‡	‡	‡	‡
H AISI 316 screws 18-8 SMo driver									‡	‡	‡	‡
I Cobalt-chromium-molybdenum untouched										1.18	4.51***	5.06***
J Cobalt-chromium-molybdenum screws AISI 420 driver											2.61*	2.89*
K Cobalt-chromium-molybdenum screws Tool steel driver												0.32
L Cobalt-chromium-molybdenum screws AISI 316 driver												

† = Difference between means is not statistically significant ($P > 0.05$).
* = Difference between means is statistically significant ($0.05 > P > 0.01$).
** = Difference between means is statistically significant ($0.01 > P > 0.001$).
*** = Difference between means is statistically significant ($P < 0.001$).
‡ = No comparison made.

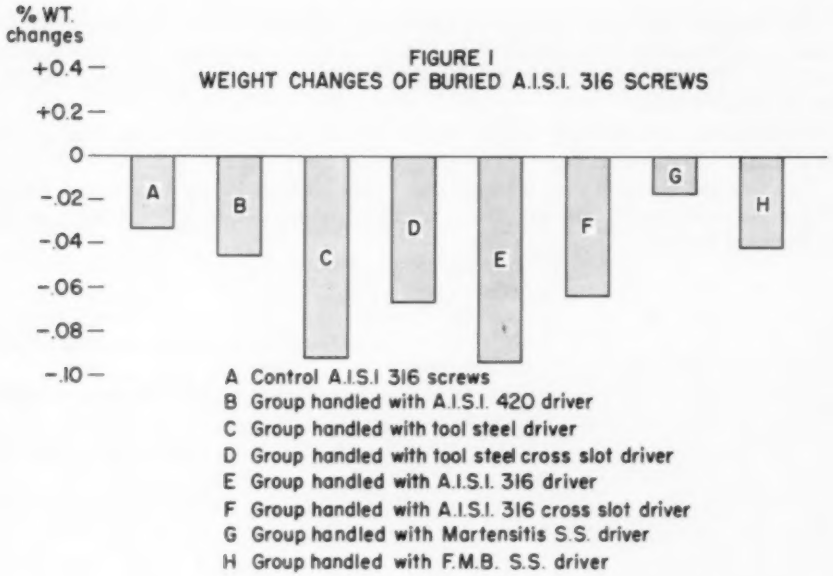

FIGURE 1
WEIGHT CHANGES OF BURIED A.I.S.I. 316 SCREWS

the nearest 0.1 milligram. In each case the average weight gain or loss in grams per 100 grams of original screw weight is given.

Weight Changes in the In Vivo Experiment

The weights in milligrams of the AISI 316 and cobalt-chromium-molybdenum screws which were placed in animals, both before and after their sojourns in the muscle, are shown in Table IV and summarized in Table VII. Again the weight changes in the case of each screw are shown in grams per 100 grams of original screw weight.

Statistical Analysis of Weight Changes

The statistical analyses were performed by C. S. Weil, M.S., Senior Research Fellow, Chemical Hygiene Fellowship, Mellon Institute of Pittsburgh. The weight changes were analyzed to determine their significance both individually and to compare group with group in both the manual and *in vivo* experiments.

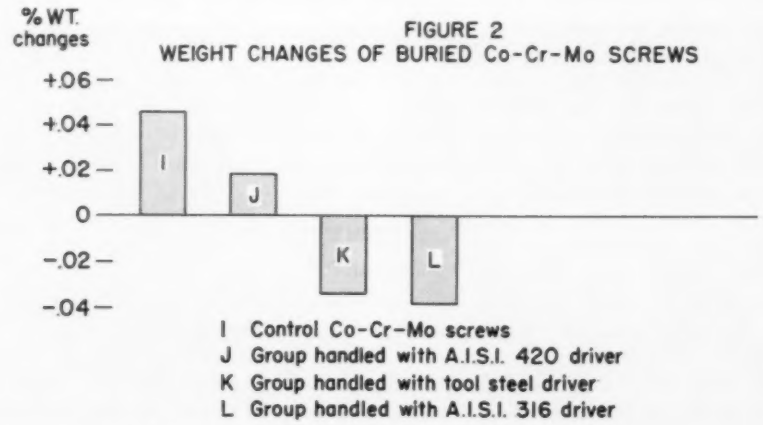

FIGURE 2
WEIGHT CHANGES OF BURIED Co-Cr-Mo SCREWS

The means of the weight changes in each batch with their standard deviations in the manual experimental results are shown in Tables V and VI together with the results of the analyses. The means and standard deviations of the *in vivo* experimental results are shown in Table VII.

A comparison between the weight changes of each group is shown in cross-reference form in Table VIII, each group being distinguished by a letter as in Table IV.

These weight changes were subjected to Fisher's t-test. Probability values were derived for the value for t^{11} through the use of the appropriate tables. Fisher's t was calculated from the formula:

$$t = \frac{M - M'}{\Sigma d^2 + \Sigma d'^2} \times K$$

where M = the mean of the weights either before handling or before burying or of the weight change in any one group;

M' = the mean of the weights after handling or after three months in the animal or of the weight change in a comparison group;

Σd^2 = the sum of the squares of the differences from the mean of each individual weight change in the first group;

$\Sigma d'^2$ = the sum of the squares of the differences from the mean of the individual weight changes in a second group; and

$$K = \frac{N\,(N')}{N + N'}\,(N + N' - 2)$$

where N is the number of screws in the first group and N′ the number in the second group.

$(N + N' - 2)$ is also equal to the number of degrees of freedom necessary in finding the probability values on Fisher's Table of t.

In these studies the following levels for statistical significance were used:

Probability of between .085 and .05 was considered possibly significant = *

Probability of between .05 and .01 was probably significant = **

Probability of .01 or less was definitely significant = ***

Manual Experiments

A comparison of the weight changes of screws after handling with the various screwdrivers is very interesting. When used on AISI 316 screws, the martensitic tool steel drivers (British) performed probably significantly better than did the AISI 316, AISI 420, or the low-alloy tool steel drivers. The 18-8 SMo (British FMB) performed possibly significantly better than did the AISI 420 or the AISI 316 driver (Tables II and V). However, the figures of these weight changes require further investigation. Radioisotopic techniques are being used to check these results.

The chromium plating on some of the drivers was lost in early pilot experiments. The ends of all the drivers may be considered free of plating in these experiments.

The weight changes in the cobalt-chromium-molybdenum (Tables III and VI) screws showed a significantly better performance of the AISI 420 driver as compared with that of the tool steel driver but not when compared with that of the AISI 316 driver.

IN VIVO EXPERIMENTS

Unhandled Control Screws (Tables IV, VII, and VIII)

The AISI 316 control group diminished in weight an average of 0.034 gram per 100 grams. The basic unhandled, but it must be added, machined, metal in this case underwent significant corrosion.

The cobalt-chromium-molybdenum alloy control screws gained 0.405 gram per 100 grams in weight in three months in muscle. This gain in weight, varying as it did from

zero to .0806 gram per 100 grams for individual screws was at first puzzling. No factual evidence can be produced to explain it. However, it is metallurgically possible that the local products of corrosion had remained adherent to the screw as surface sludge and would have required more vigorous cleansing to remove them to reveal weight loss. This is however pure speculation. A gain in weight was found only in two groups of cobalt-chromium-molybdenum screws and did not affect the validity of the weight changes in the AISI 316 screws.

Handled Screws (Tables IV, VII, and VIII)

The screws to which the martensitic stainless-steel driver had been applied showed a loss of weight of only 0.0174 gram per 100 grams which is not significantly greater than that of the control group. This loss is possibly significantly less than that of AISI 316 screws handled with AISI 316 cross-slotted (−0.0624 gram per 100 grams) and tool steel cross-slotted (−0.0662 gram per 100 grams) drivers. It is probably significantly less than the loss of the tool steel single-slotted group (−0.0927 gram per 100 grams). It is not significantly less than the −0.0419 gram per 100 grams loss of the group turned with the 18–8 SMo (FMB) stainless-steel driver or the −0.0446 gram per 100 grams loss of the group turned with the AISI 420 driver. However the group turned

Fig. 3: Low-power view of tissue section showing the outline of a screw in its muscle bed (hematoxylin and eosin, × 7).

Fig. 4-A: Photomicrograph (× 120) of section stained with hematoxylin and eosin to show the minimal tissue reaction near unhandled cobalt-chromium-molybdenum screw slot. Note the absence of fibrosis of the fat that had lain in the screw slot. There are a few flattened cells at the metal-tissue interface.

Fig. 4-B: Photomicrograph (× 120) of tissue section to show the slightly thicker lining membrane excited by an unhandled AISI 316 screw slot. Some young fibrous tissue is seen containing a few vessels. The fat cells and muscle fibers are unaffected.

FIG. 3

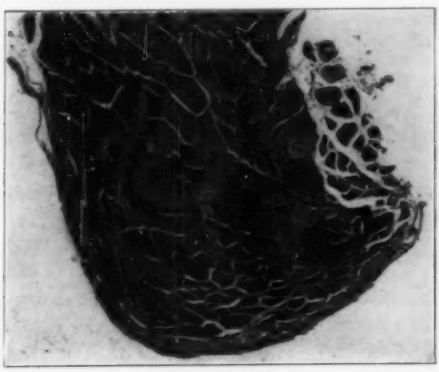

FIG. 4-A

FIG. 4-B

with the martensitic drivers performed much better than that with the AISI 316 single-slotted drivers (−0.0946 gram per 100 grams). In connection with the similar behavior of screws handled with the martensitic and the AISI 420 drivers, it will be noted from Table I that these steels are very similar in specification.

The main difference between the specification of AISI 316 and of 18–8 SMo (FMB) is the lower content of nickel in the latter, that is, 8 per cent as compared with 10 to 14 per cent in the former. The fact that the FMB-driver group (−0.0419 gram per 100 grams) performed significantly better than did the AISI 316 group (−0.0946 gram per 100 grams) when handling AISI 316 screws points out the danger of too exact a similarity between tool and screw specification. Under these latter circumstances, maximal metallic transfer can occur. Even a slight difference in composition or an increase in hardness of the tool may reduce this transfer [5, 8].

Single-Slotted versus Cross-Slotted Drivers (Table VII)

Any influence of cross-slotted screwdrivers in cutting down slipping in the screw slot is not shown here. In the case of the screws handled with the appropriate tool steel and AISI 316 drivers no statistically significant difference was seen between the cross-slotted and single-slotted drivers. This may well be due to the influence of plastic deformation of the screw slots in these groups initiating corrosion.

Influence of Hardness of the Driver

Most screws were made with a small-grain size and a hardness factor of 28 to 35 on the Rockwell-C scale. Drivers were usually harder for longer life. In the case of the AISI 316 screws the two groups showing the greatest weight losses were those handled with the tool steel (hardness of Rockwell-C 57 to 59) and those with AISI 316 (hardness of Rockwell-C 30 to 35) single-slotted drivers. Thus the hard tool steel caused as much corrosion as the softer AISI 316 driver. This apparent incongruity is perhaps due to there being two factors involved. The tool steel is hard and therefore gave less metallic transfer, but it did damage the screw slot and deform the grains. This may have set up centers of corrosion by reaction between the plastically deformed areas and the undeformed areas of the metal. On the other hand the AISI 316 drivers, being exactly similar in composition and hardness to the screws, produces maximal metallic transfer and little plastic deformation, and thus maximal corrosion occurred for another reason.

Handled Cobalt-Chromium-Molybdenum Screws (Table VII)

All these groups performed significantly better than the corresponding AISI 316 screws. The screws handled with the AISI 420 driver gained 0.0182 gram per 100 grams during the experiment and performed in a statistically similar fashion to the control unhandled group. The cobalt-chromium-molybdenum with tool steel and AISI 316 drivers lost significant amounts of weight and compared unfavorably with the AISI 420 group.

HISTOLOGY

As stated previously, two sections from each tissue block were examined. One was stained with hematoxylin and eosin to show tissue reaction, and one to show iron salts by the Prussian-blue reaction. The blocks were then preserved for spectrographic analysis. The blocks were cut to show the maximum metal-tissue interface (Fig. 3).

Unhandled Control Screws

Some tissue reaction was seen around all screws. A fibrous-tissue membrane surrounded every screw and varied in thickness. In general it may be said that the tissue reaction to the cobalt-chromium-molybdenum screws was much less than that to the AISI 316 screws. This was shown by the lining membrane at the tissue-metal interface

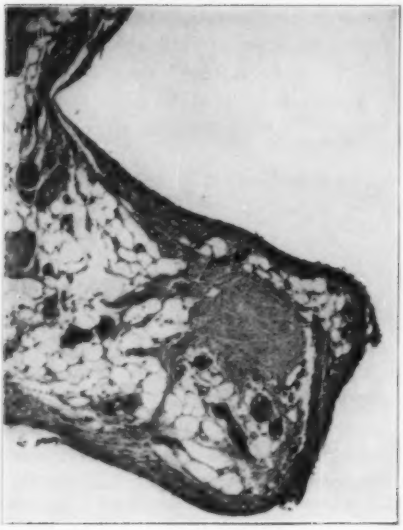

FIG. 5-A

FIG. 5-B

Figs. 5-A through 5-D: Photomicrographs showing the typical reaction of the tissue lying in handled screw slots.

Fig. 5-A: Vitallium showing some fibrosis of the tissue with small blood vessels and a thicker lining membrane than that shown in Fig. 3 (× 120).

Fig. 5-B: AISI 316 screw slot showing iron-salt crystals giving the Prussian-blue reaction and showing as black specks (× 120).

FIG. 5-C

FIG. 5-D

Fig. 5-C: Transverse section of tissue lying in screw slot of AISI 316 screw heavily handled with screwdriver, showing masses of dark iron salts (× 120). (Reprinted by permission from *Modern Trends in Surgical Materials*, edited by Leon Gillis. London, Butterworth and Co., Ltd., 1958.)

Fig. 5-D: Detail of part of Fig. 5-C showing the crystals of iron and other metals lying within large histiocytes (× 1000). (Reprinted by permission from *Modern Trends in Surgical Materials*, edited by Leon Gillis. London, Butterworth and Co., Ltd., 1958.)

being only one or two cells thick around the cobalt-chromium-molybdenum screws (Fig. 4-A), and often being many cells thick and fairly vascular around the stainless-steel screws (Fig. 4-B). Sections stained to show iron salts demonstrated none at all around the cobalt-chromium-molybdenum screws and traces round the AISI 316 controls. This demonstrates again that slight corrosion can always occur with stainless steel even in the absence of handling.

In no case was there any polymorphonuclear or round-cell infiltration that might be indicative of infection or of a severe reaction to the metal.

Handled Screws

A greater cellularity at the metal-tissue interface around the screw head was characteristic of all handled screws and this often amounted to a very vascular fibrosis in the screw slot (Figs. 5-A through 5-D).

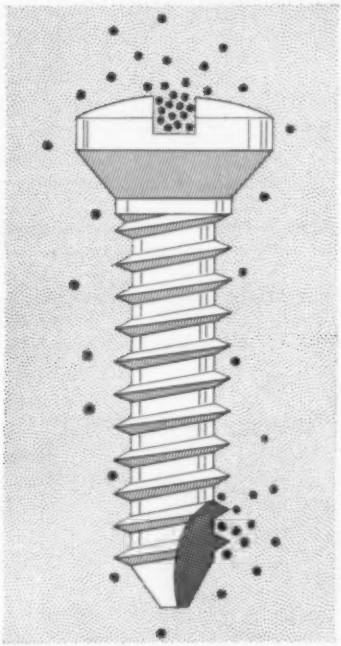

FIG. 6

Fig. 6: A diagrammatic representation of a typical section of a tissue specimen showing the outline of the screw at the metal-tissue interface. The typical distribution of iron salts around an AISI 316 screw is shown, being denser around the screw slot, and where the self-tapping slot damages the last thread.

The sections stained to show iron salts showed very little around the cobalt-chromium-molybdenum screws although a few blue granules were usually found near the screw slot. Since the cobalt-chromium-molybdenum alloy contains less than 1 per cent of iron (Table I), this was only to be expected; the iron seen was probably derived from transferred steel from the drivers.

All the specimens from around handled AISI 316 screws showed iron infiltration varying in degree from mild to heavy. These iron salts were always found in maximum concentration around the screw slots and heads, and little if any was found around the middle screw threads, while some was generally found at the site of the self-tapping slots at their lower ends (Fig. 6).

Summary of Histological Results

In general the control cobalt-chromium-molybdenum screws were more inert than the control AISI 316 screws. Both handled cobalt-chromium-molybdenum and AISI 316 screws showed a greater tissue reaction than the corresponding unhandled controls. In all these handled screws the cellularity at the tissue-metal junction was maximal around the screw slots and screw heads, and the maximum amount of iron deposition was always found in these areas. As far as differences between the various groups go, they paralleled the differences in weight changes. It must be said, however, that each biopsy specimen is merely one still out of a moving picture. The electrolytic process of corrosion set up by the metallic transfer is a continuous process. These studies confirm that the handled part of an implanted metal produces a greater tissue reaction than do the unhandled parts. They are not, however, easy to grade nor are they susceptible to statistical analysis.

CONCLUSIONS

Metallic transfer from screwdriver to screw appears to adversely influence the corrosion resistance of the screw. A judicious balance between composition and hardness must

be aimed at in selecting a suitable screwdriver. The composition of the driver must be related to that of the screw. Of the screwdrivers tested, one of AISI 420 stainless steel appears to be most suitable for both AISI 316 and cobalt-chromium-molybdenum screws. Its hardness of Rockwell-C 49 to 51 is hard enough for good wear but the driver should certainly be no harder than this if excessive mechanical damage to the screws is to be avoided. About Rockwell-C 40 would appear to be a happy compromise as far as screw corrosion goes.

One may speculate that a cobalt-chromium-molybdenum alloy screwdriver of greater hardness than the screws made of the same alloy might be the ideal one for handling these screws.

Further radioactive-isotopic experiments have been undertaken to determine the amount of metallic transfer between screwdrivers and screws of various alloys and will be reported shortly.

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Supervoltage Radiation for Sarcomata of the Pelvis and Lower Extremities

A Preliminary Report *

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In the extensive list of papers on the treatment of patients with primary malignant tumors of the pelvic bones and the upper portions of the femora, surgical intervention is reported as being the most commonly employed form of treatment. The more significant of these [1-18,20] are listed at the conclusion of this paper. Hemipelvectomy [16] has become the procedure of choice. Initially operative mortality was high, but in more recent reports [12,18] there have been no operative deaths. The results following surgery, however, have been disappointing in many instances.

With the advent in 1949 of supervoltage radiation therapy, a different approach to the problem became available. This paper deals with our experience in the treatment of eleven patients with primary malignant tumors of the bones of the hip or thigh. In addition, one patient with Ewing's sarcoma of the distal portion of the fibula is included because the same program of treatment was employed; the patient was followed for over six years after treatment.

The diagnosis in early cases was determined by microscopic study of tumor tissue obtained by open operation; in later years tissue was obtained by Turkel needle biopsy [19] performed under fluoroscopic control. After the diagnosis was established, the patient was then given supervoltage irradiation produced by the two-million-volt Van de Graaff generator.

Surgery was the initial treatment in Cases 1 and 2 and was employed as a supplementary procedure in Case 12.

RADIATION THERAPY

The well established skin-sparing effect of supervoltage irradiation permits the use of larger depth dosages to a more inclusive portal than was previously possible. A more uniform dosage through bone and soft tissue can be delivered with supervoltage x-ray than is possible with conventional methods.

Treatment is effected by means of anterior-posterior opposing portals, rotational, or sector-scanning fields. In Figure 1, a typical anterior portal directed to a chondrosarcoma of the pelvis is sketched; the same volume is delivered posteriorly on alternate days. A second method of treatment is by rotation; the patient is rotated 360 degrees with the x-ray beam directed to the axis of the tumor throughout the treatment period. With this method the overlying skin and subcutaneous structures receive only a fraction of the desired dose to the bone tumor. In the third method only a sector or segment of the complete 360-degree rotation is utilized. In patients treated by means of this method, the amount of irradiation to the skin and subcutaneous structures falls somewhere between that given by the full rotation technique and that given by the opposing portal technique. This technique is employed when it is desirable or necessary to eliminate radiation from closely adjacent tissues, for example, sparing the testes in the treatment of an expanding low pelvic bone lesion.

* Acknowledgment is made of the cooperation of the Massachusetts Institute of Technology in the physical aspects of this work.

The group of cases treated included six chondrosarcomata, two fibrosarcomata, two mixed sarcomata, one reticulum-cell sarcoma, and, finally, one Ewing's sarcoma of the fibula. The lesion was treated by tumoricidal doses of irradiation which ranged from 2400 r to 7500 r, depending upon the type of tumor treated. Generally, the dosage delivered to the central area of chondrosarcoma or mixed sarcoma was 6000 r; resistant fibrosarcoma was treated by 7500 r; and reticulum-cell sarcoma and Ewing's sarcoma, considered more sensitive, were treated by a maximum of 3000 r in any one treatment series.

DISCUSSION OF CASES

Chondrosarcomata are considered radioresistant tumors: our results bear this out.

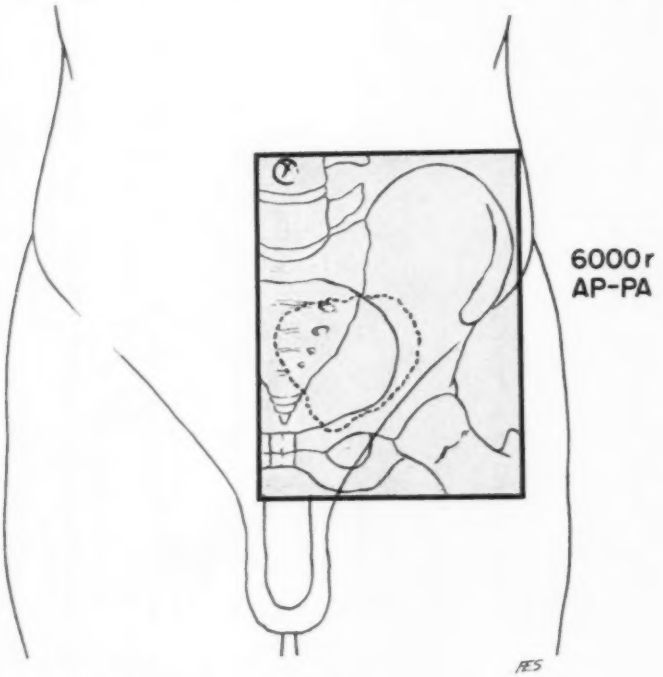

FIG. 1

Treatment of chondrosarcoma with two mev. x-ray, anterior portal; patient treated posteriorly on alternate days.

The lesions treated were extensive and in several instances surgery was considered out of the question. Palliative relief of symptoms was obtained in all patients; of the six patients reported, three (Cases 8, 9, and 11) were living with follow-up periods of twenty-two, eighteen, and ten months, respectively. One patient (Case 4) died thirty-two months after treatment from pulmonary metastases. It is to be noted that the primary lesion in this patient was subjected to biopsy again, approximately sixteen months after irradiation, and the tissue obtained showed chronic inflammation and degeneration of muscle and bone. A few necrotic cells were seen but no tumor cells were found. The patient who survived thirty-two months (Case 6) died as a result of local extension.

Of the patients with chondrosarcoma, the patient (Case 1) who had the longest survival was initially operated upon and was then treated with conventional x-ray therapy in 1944. He survived until March 1955, an interim of 130 months. The precipitating cause of death was reported to be pelvic lymphatic obstruction and kidney failure. Until the

TABLE I

SUMMARY OF CASES

Case	Age (*Years*) and Sex	Date of Biopsy	Radiation Data *	Survival	Comment
1 R. D.	33 M	4-10-44: microscopic diagnosis, osteochondrosarcoma, right innominate bone	1944: 1800 r to right pelvic portal (AP-PA) 1949: 6000 r to pelvic sphere (rotation) 1951: 6000 r to tumor extension in right lower quadrant in abdominal wall (AP-PA) 1951: 5400 r to node in left groin (AP portal) 1952: 6000 r to right thigh with pelvic overlap (AP-PA) 1954: 6000 r to left thigh below region previously treated (AP-PA) 1954: 6000 r to left thigh (AP-PA)	10 yrs. and 10 mos. after x-ray treatment	Until a year before death, was very active; immediate cause of death was pelvic lymphatic obstruction and kidney failure
2 L. B.	56 F	8-11-50: microscopic diagnosis, fibromyxosarcoma, right popliteal space	1951: 6000 r to 11 by 15 cm. portal (rotation)	Alive and well 5 yrs. and 3 mos.; chest x-ray negative	Local excision done 4 times before irradiation given, amputation refused
3 T. S.	55 M	9-20-51: microscopic diagnosis, reticulum-cell sarcoma, lower part of right acetabulum	1951: 3000 r to acetabular area (rotation)	Alive and well 5 yrs. and 9 mos.; chest x-ray negative	
4 A. A.	44 M	1-31-53: microscopic diagnosis, chondrosarcoma, upper portion of the right femur	1953: 6000 r to 20 by 17 cm. portal (AP-PA)	Deceased at 2 yrs. and 8 mos., of pulmonary metastases	Biopsy repeated 12-20-54 at original site of tumor; a few necrotic cells but no tumor cells found
5 E. H.	76 F	2-19-53: microscopic diagnosis, fibrosarcoma of left thigh	1953: 7500 r to 17 by 25 cm. portal (rotation)	Alive and well 3 yrs. and 10 mos.; chest x-ray negative	Some persistent osteoporosis of region treated; no fracture
6 S. T.	46 M	4-18-53: microscopic diagnosis, low-grade chondrosarcoma, left innominate bone	1953: 6000 r to 20 by 17 cm. portal (AP-PA)	Deceased 2 yrs. and 8 mos. after biopsy	Alive and active for 13 mos., then abdominal metastases gradually developed

7	P. C.	58 M	6-3-53: microscopic diagnosis, undifferentiated sarcoma, upper portion of the right thigh, highly malignant	1953: 2400 r to 32 by 32 cm. portal (AP-PA)	Alive and well 3 yrs.; chest x-ray negative	Because condition was considered hopeless, treatment was terminated
8	C. C.	66 F	10-21-55: microscopic diagnosis, chondrosarcoma, upper part of the left femur	1955: 6000 r to 11 by 37 cm. portal using 220 sector-scanning	Alive 1 yr. and 10 mos.; essentially asymptomatic	After x-ray therapy, transient lymphoedema of lower extremity, which rapidly disappeared
9	J. M.	67 F	1-26-56: microscopic diagnosis, chondrosarcoma of left femur	1956: 6000 r to 17 by 27 cm. portal (oblique opposing portals)	Alive and well 1½ yrs.	Tremendous reduction in size of mass during treatment; transient lymphoedema of lower extremities
10	J. P.	24 F	8-15-56: microscopic diagnosis, fibrosarcoma of right hip and buttock	1956: 7500 r to 11 by 21 cm. portal (AP-PA)	Alive and well 13 mos.	
11	A. L.	63 M	11-5-56: microscopic diagnosis, chondrosarcoma of right innominate bone; x-rays revealed pathological fracture of pubic ramus	1956: 6000 r to 18 by 20 cm. portal (AP-PA)	Alive and well 10 mos.; very active, no symptoms	Back at work as postman; chest x-ray negative
12	J. S.	24 F	2-13-51: microscopic diagnosis, Ewing's sarcoma, distal portion of the right fibula	1951: 1800 air dose each of two 5 by 16 cm. portals (AP-PA)	6 yrs. and 8 mos., living and well	5 pregnancies since diagnosis and institution of treatment, all children living and well
			Metastatic inguinal node removed on 11-8-51	1951: 3000 r directed to left leg (rotation)		
				1951: 800 r to both lung fields		
				1952: 2400 r to mediastinal portal (AP-PA)		
				1952: 3000 r to left thigh		
				1952: 2400 r to include left side of abdomen and inguinal areas (AP-PA)		
				1952: 2400 r to mediastinal portal (AP-PA)		

* All dosages given with 2 mev. and delivered to the tumor itself. AP = Anteroposterior opposing portals. PA = Postero-anterior portals.

last year of his life he was very active in carrying on his usual work and appeared to be in excellent condition. Multiple surgical procedures on this patient were necessitated by local extension and recurrences from the time of the initial biopsy up to January 1954. Repeated courses of irradiation were given (Table I). Surgery and irradiation were of considerable aid in alleviating symptons; but, as is so often seen in chondrosarcoma, the tumor remained viable despite all treatment.

The two patients with fibrosarcoma (Cases 5 and 10) were treated by 7500 r directed to the lesion; these patients were living and were relatively comfortable forty-six months

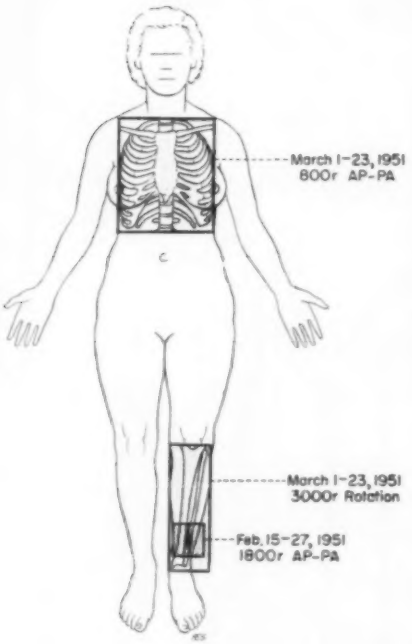

FIG. 2-A

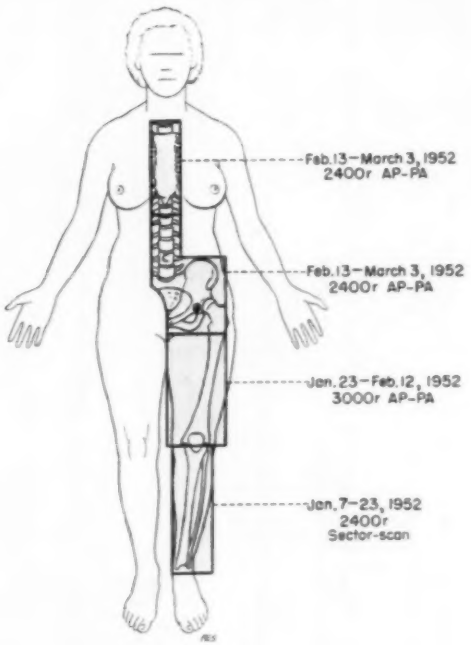

FIG. 2-B

Fig. 2-A: Ewing's sarcoma of fibula (see Table for data on treatment).
Fig. 2-B: Inguinal node positive for cancer cells. Use of portals as previously outlined.

and thirteen months, respectively, after treatment. Admittedly, the result in neither case can be considered conclusive at this time.

The results in patients with mixed sarcoma are interesting inasmuch as one patient (Case 2) had had four definitive surgical excisions between August 1950 and July 1951 prior to irradiation. Amputation was advised but was refused by the patient. Sixty-three months after irradiation there was no evidence of recurrence and no complication from irradiation. The other patient (Case 7) had chondrofibrosarcoma and was living and well thirty-six months after irradiation. Treatment in this patient was terminated at 2400 r as the situation was considered hopeless. The tissues were foul and necrotic; despite this the patient continued to refuse amputation. Follow-up examination thirty-six months later revealed no evidence of disease. In retrospect, while the tumor was classified histologically as highly malignant, it was apparently satisfactorily sensitive to the amount of irradiation given.

The sixty-nine-month survival of the patient (Case 3) with reticulum-cell sarcoma of the acetabulum, given 3000 r, substantiates the possibility of an adequate response to

treatment of this type of tumor. This patient had no evidence of recurrence and his activities were unlimited when he was last seen.

The results of treatment of Ewing's sarcoma of the left fibula (Case 12) are particularly gratifying; eighty months after the initial therapy the patient was alive and well. The patient, a woman, twenty-four years old, was treated by 400 kilovolts radiation between February 15 and February 27, 1951, with a dose of 1800 r delivered from opposing portals. Additional treatment was believed indicated and 3000 r was given with the two-million-volt Van de Graaff apparatus, by means of the rotational portal. During this same course of therapy 800 r was directed to both lung fields in the mid-plane of the chest. The daily dose used in the treatment of this patient varied from 160 to 180 r, depending on the size of the portal. This represents the dosage delivered to the site of the tumor. Treatment was completed to any one portal in fifteen to eighteen days.

The patient did extremely well and the lesion of the left fibula healed satisfactorily. A metastatic lesion involving a left inguinal node developed in November 1951. After a confirmatory biopsy, additional radiation therapy was carried out; 2400 r was directed to the leg (the fibular lesion), followed by 3000 r to the rest of the left lower extremity and 2400 r to the left groin and left side of the abdomen. These fields were contiguous.

The calculated dose to the left ovary was 2400 r. The right ovary, however, was not included in the portal but did receive about 100 r from the left pelvic field.

The mediastinal nodes were treated by 2400 r between February 13 and March 3, 1952. This treatment was directed to the entire, pertinent, lymphatic drainage system from the left ankle to its venous termination in the mediastinum (Figs. 2-A and 2-B).

It is particularly interesting to note that not only was this girl well and free of symptoms at the time of writing, but she had had five normal pregnancies since the initial x-ray therapy was instituted.

RADIATION SIDE EFFECTS

Severe radiation damage to skin, intestine, and bone is always a possibility whenever large radiation doses are administered. Complications from supervoltage irradiation in this group of patients have been proportional to the type of tumor and the dose of x-rays required. With dosages of 6000 to 7500 r, moderate fibrosis of the subcutaneous and deep tissues occurred in several of the patients, but the resultant lymphoedema of the lower extremity was transient and adequately controlled by an elastic stocking. Disabling fibrosis, however, is always a possibility.

When considerable demineralization of bone is present at the onset of treatment, fracture may occur; and while the latter cannot be completely controlled when large tumoricidal doses are indicated, its possibility can be minimized by the use of crutches during and after treatment until the bone has been re-established. The incidence of fracture is lowered by the use of supervoltage x-ray rather than conventional x-ray inasmuch as the energy absorbed by the bone is less with the former type of therapy. None of the patients in this group sustained a pathological fracture.

With large tumors of the pelvis it is difficult to determine whether bowel symptoms are secondary to encroachment by the tumor or to radiation changes within the bowel. A barium enema prior to the use of x-rays is helpful in determining the cause of symptoms and treatment indicated. Of this group of patients, Case 6 experienced colon symptoms. A barium enema before treatment was begun revealed encroachment upon the lumen of the colon and appreciable deviation of the rectum and sigmoid. It is probable that a part of the symptoms complained of after irradiation were directly attributable to the radiation, but local extension of the tumor was also considered a contributing factor. This patient died with advanced local extension.

Another complication, radionecrosis of the skin, was not encountered in any of these patients despite the large doses of x-ray administered.

SUMMARY

Although this is a preliminary report and some of the patients have not been observed over a sufficiently long period of time for the results to be considered conclusive, the use of supervoltage radiation treatment in primary malignant tumors of the bones of the pelvis and lower extremities consistently gave palliative relief and in some instances a long-term survival without evidence of recurrence.

NOTE: To Miss Gracia Halladay, R.N., the authors express their appreciation for aid in correlating patient data.

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Preliminary Report of the Committee on Fractures and Traumatic Surgery on the Use of a Prosthesis in the Treatment of Fresh Fractures of the Neck of the Femur*

BY FRED C. REYNOLDS, M.D., ST. LOUIS, MISSOURI

Four years ago the Committee on Fractures and Traumatic Surgery began a study to delineate more clearly the place, if any, of a prosthesis in the management of fresh fractures of the neck of the femur. At the outset we adopted the premise that excision of the proximal fracture fragment of the neck of the femur and its replacement with a foreign body was a radical procedure. To be justified, it must have definite and unmistakable advantages over any and all other methods of therapy for this condition. The procedure should not be more hazardous, nor the postoperative complications greater, than with the usual methods of internal fixation. In addition, these foreign bodies must withstand the test of time.

Management of this difficult lesion by eliminating the fractured portion of the bone and substituting a prosthesis is attractive in that one would expect earlier ambulation of the patient and shortening of the period of hospitalization and postoperative disability. In addition, it would avoid the danger of non-union and aseptic necrosis. Besides determining whether these suppositions were correct, we wanted answers to the following questions:

1. Did one type or form of prosthesis have merit over others?
2. Was there a preferred operative technique for insertion of the prosthesis?
3. What was the best method of postoperative management?
4. Was the use of a prosthesis most applicable in a particular type of patient or fracture?

It was realized that the number of patients operated upon by members of this committee would not be great; however, it was felt that a careful study of this small group would perhaps yield more information than could be obtained by a widely circulated questionnaire. This report is made possible only because the members of the committee have faithfully kept track of their patients and reported their experiences to me.

I must stress that this is my interpretation of these reports, although I have attempted to be as objective as possible; I am sure that there are results which I have considered unsatisfactory that others would consider satisfactory if the conditions and circumstances were presented. That a patient could not walk following operation, and the result was thus a failure, does not necessarily mean that all that was expected of the procedure was not obtained. However, in a study such as this, inability to walk must indicate failure. The results, therefore, must be considered as approximations or trends. I have no doubt that others going over these same records would arrive at different figures; if any of us had an opportunity to examine all of the cases, the figures would again be different.

We considered all untreated fractures of the neck of the femur that were operated upon within the first four weeks following the injury to be fresh fractures. For the purpose of classification, the results were classified: *excellent, good, fair, poor, still on crutches, never walked, lost to follow-up, died before rating,* and *not graded* (due to lack of information).

Criteria for classification are as follows. For an excellent result the patient must have a stable, relatively painless hip in which there is a nearly normal range of motion; he must

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1957.

TABLE I

SUMMARY OF CASE REPORTS OF 228 PATIENTS IN WHOM PRIMARY PROSTHETIC TREATMENT WAS EMPLOYED FOR FRESH FEMORAL-SHAFT FRACTURES

Results	No. of Patients	Average Age (*Years*)	Average Elapsed Time from Fracture to Operation (*Days*)	Surgical Approach		Repair of Joint Capsule	
Satisfactory							
Excellent	19	73.55	8.58	Anterior	9	Repaired	12
				Posterior	9	Partial	1
				Unknown	1	Unknown	6
Good	44	71.47	7.84	Anterior	21	Repaired	18
				Posterior	23	Not repaired	8
						Partial	7
						Unknown	11
Fair	37	75.27	9.71	Anterior	9	Repaired	9
				Posterior	28	Not repaired	11
						Partial	11
						Unknown	6
Total satisfactory	100	73.43	8.71	Anterior	39	Repaired	39
				Posterior	60	Not repaired	19
				Unknown	1	Partial	19
						Unknown	23
Unsatisfactory							
Poor	26	75.38	6.06	Anterior	11	Repaired	5
				Posterior	13	Not repaired	5
				Unknown	2	Partial	3
						Unknown	13
Still on crutches	21	72.09	7.00	Anterior	16	Repaired	4
				Posterior	5	Unknown	17
Never walked	16	82.37	8.92	Anterior	1	Repaired	10
				Posterior	15	Not repaired	1
						Partial	1
						Unknown	4

TABLE I

SUMMARY OF CASE REPORTS OF 228 PATIENTS IN WHOM PRIMARY PROSTHETIC TREATMENT WAS EMPLOYED FOR FRESH FEMORAL-SHAFT FRACTURES

Type of Prosthesis Used				Type of Postoperative Fixation				Average Elapsed Time from Operation to Walking (*Days*)	Average Hospital Stay (*Days*)	Average Follow-up Period (*Months*)
Roger Anderson	2			Boots	4			17.77	31.33	22.15
Judet	1			Traction	8					
J.E.M. Thomson (light bulb)	1			None	2					
Austin Moore	4			Unknown	5					
Fred Thompson	10									
Unknown	1									
Eicher	8			Boots	4			28.47	32.88	22.95
Judet	3			Traction	12					
J.E.M. Thomson (light bulb)	12			None	11					
Austin Moore	9			Unknown	17					
Naden-Reith	2									
Fred Thompson	10									
Roger Anderson	4			Boots	10			27.80	35.94	30.47
Eicher	1			Traction	2					
Judet	8			None	3					
J.E.M. Thomson (light bulb)	21			Unknown	22					
Austin Moore	1									
Naden-Reith	1									
Fred Thompson	1									
Roger Anderson	6	Austin Moore	14	Boots	18			24.68	33.38	25.19
Eicher	9	Naden-Reith	3	Traction	22					
Judet	12	Fred Thompson	21	None	16					
J.E.M. Thomson (light bulb)	34	Unknown	1	Unknown	44					
Roger Anderson	3	Austin Moore	3	Boots	4	Unknown	12	21.66	55.00	18.04
Eicher	1	Naden-Reith	1	Traction	7					
Judet	7	Fred Thompson	4	Pillow splint	1					
J.E.M. Thomson (light bulb)	7			None	2					
Eicher	1			Boots	11			21.33	39.25	6.84
Judet	12			Traction	9					
Austin Moore	3			None	1					
Naden-Reith	3									
Fred Thompson	2									
Roger Anderson	9			Bed	1	Hip spica	1		74.20	16.61
Judet	4			Boots	10	Unknown	2			
J.E.M. Thomson (light bulb)	2			Traction	1					
Austin Moore	1			Pillow splint	1					

TABLE I *(Continued)*

Results	No. of Patients	Average Age (*Years*)	Average Elapsed Time from Fracture to Operation (*Days*)	Surgical Approach	Repair of Joint Capsule
Total unsatisfactory	63	76.61	7.33	Anterior 28 Posterior 33 Unknown 2	Repaired 19 Not repaired 6 Partial 4 Unknown 34
Total group rated	163	75.02	8.02	Anterior 67 Posterior 93 Unknown 3	Repaired 58 Not repaired 25 Partial 23 Unknown 57
Group not rated Died	40	80.12	5.81	Anterior 16 Posterior 23 Unknown 1	Repaired 17 Not repaired 10 Partial 3 Unknown 10
Lost to follow-up	23	76.08	5.27	Anterior 11 Posterior 11 Unknown 1	Repaired 11 Unknown 12
Insufficient data	2	71.00	2.00	Anterior 1 Posterior 1	Not repaired 1 Unknown 1
Total group not rated	65	75.73	4.36	Anterior 28 Posterior 35 Unknown 2	Repaired 28 Not repaired 11 Partial 3 Unknown 23
Total entire series	228	75.26	6.80	Anterior 95 Posterior 128 Unknown 5	Repaired 86 Not repaired 36 Partial 26 Unknown 80

TABLE I *(Continued)*

Type of Prosthesis Used				Type of Postoperative Fixation				Average Elapsed Time from Operation to Walking (*Days*)	Average Hospital Stay (*Days*)	Average Follow-up Period (*Months*)
Roger Anderson	12	Austin Moore	7	Boots	25	Pillow splint	2	21.49	56.15	13.83
Eicher	2	Naden-Reith	4	Traction	17	None	3			
Judet	23	Fred Thompson	6	Bed	1	Unknown	14			
J.E.M. Thomson (light bulb)	9			Hip spica	1					
Roger Anderson	18	Austin Moore	21	Boots	43	Pillow splint	2	23.09	44.76	19.51
Eicher	11	Naden-Reith	7	Traction	39	None	19			
Judet	35	Fred Thompson	27	Bed	1	Unknown	58			
J.E.M. Thomson (light bulb)	43	Unknown	1	Hip spica	1					
Roger Anderson	6	Austin Moore	5	Boots	11			19.28	35.22	2.10
Eicher	2	Naden-Reith	1	Traction	9					
Judet	6	Fred Thompson	7	None	4					
J.E.M. Thomson (light bulb)	13			Unknown	16					
Roger Anderson	3			Boots	1			44.33	34.43	
Judet	3			Traction	9					
Austin Moore	10			Hodgen splint	1					
Naden-Reith	2			Body cast	1					
Fred Thompson	5			None	1					
				Unknown	10					
Judet	1			Boots	1				23.00	10.5
J.E.M. Thomson (light bulb)	1			Unknown	1					
Roger Anderson	9	Austin Moore	15	Boots	13			31.80	30.88	6.30
Eicher	2	Naden-Reith	3	Traction	18					
Judet	10	Fred Thompson	12	Hodgen splint	1					
J.E.M. Thomson (light bulb)	14			Body cast	1					
				None	5					
				Unknown	27					
Roger Anderson	27			Boots	56			25.99	40.14	15.10
Eicher	13			Traction	57					
Judet	45			Bed	1					
J.E.M. Thomson (light bulb)	57			Hip spica	1					
Austin Moore	36			Pillow splint	2					
Naden-Reith	10			Hodgen splint	1					
Fred Thompson	39			Body cast	1					
Unknown	1			None	24					
				Unknown	85					

TABLE II

COMPLICATIONS

Result	Complication	No. of Patients
Excellent	Pressure sore on heel	1
Good	Pneumonia	1
	Acute cholecystitis	1
	Superficial phlebitis	1
	Coliform bacteria cyst	1
	Deep slough over Achilles tendon	1
	Superficial wound infection	1
	Fracture of femoral shaft at operation	2
	Marked arthritis	1
	Post-irradiation fracture	1
	Dislocated hip	1
Fair	Superficial wound infection	1
	Absorption around stem	3
	Thrombophlebitis	1
	Early postoperative dislocation; readily reduced	1
	Cardiovascular condition preventing walking	1
	Temporary peroneal weakness postoperatively	1
	Temporary foot-drop after removal of cast	1
	Activity restricted by mild stroke	1
	Some calcification in joint capsule	1
Poor	Subluxation	1
	Deep infection resulting in removal of prosthesis	2
	Cerebral vascular accident resulting in spastic hemiplegia and severe aphasia	1
	Bone absorption	2
	Absorption around stem	1
	Hip dislocation	2
	Hemiplegia with terminal stroke	1
	Prosthesis replaced	3
Still on crutches	Superficial wound infection	1
Never walked	Absorption around stem	1
	Bilateral peroneal palsy	1
	Prosthesis removed	1
	Bronchial pneumonia	2
	Superficial wound infection	2
	Cerebral thrombosis	1
Died	Dislocation of prosthesis	2
	Pulmonary embolism	2
	Cerebral vascular accident postoperatively	1
	Cerebral accident	1
	Hemiplegia	2
	Cerebral vascular damage	1
	Coronary	1
	Cardiorenal failure	2
	Partial paralysis	1
	Terminal pneumonia	2
	Superficial infection	1
	Embolus	1
	Dislocation of hip postoperatively	1
	Uraemia	1
	Pulmonary oedema	2

TABLE II *(Continued)*

Result	Complication	No. of Patients
	Pneumonia	4
	Cardiac with embolus to leg	1
	Decubitus ulcers	1
Lost to follow-up	Intertrochanteric fracture	1
	Trochanteric fragment fractured at operation	1
	Thrombophlebitis	1
	Hip dislocation	1
	Fever of unknown origin	1
Total		77

be able to walk without support and have good endurance. The requirements for a good result were the same, but the patient used a cane or a crutch for support at times. A result was fair if the patient required a cane or crutch most of the time, or had either moderate pain on walking or poor endurance, or both. A poor result is one in which the patient had considerable pain or was not ambulatory to any degree. The results in those who never walked, and those requiring replacement of the prosthesis are, of course, failures. In addition, those results listed *still on crutches* were considered unsatisfactory.

Records of 228 cases are available for study (Table I). The average age of these patients was 75.26 years. The average time from fracture to operation was 6.80 days. An anterior approach was employed in ninety-five patients, a posterior approach in 128, and the type of approach was not stated in five. The average hospital stay was 40.14 days.

The types of prostheses and the number of each used were as follows: Fred Thompson, thirty-nine; Eicher, thirteen; Naden-Reith, ten; Judet, forty-five; Roger Anderson, twenty-seven; Austin Moore, thirty-six; J.E.M. Thomson (light bulb), fifty-seven; and type not stated, one.

Ambulation was begun following surgery on an average of between three and four weeks. Postoperative fixation was employed in a surprising number of cases, although its duration was short.

Seventy-seven postoperative complications were reported, many of a minor nature (Table I). The problem of postoperative dislocation and fracture of either the trochanter or shaft of the femur, although quite serious in many of these patients, occurred for the most part early in each surgeon's experience with this procedure and is not considered so much of a risk at the present time. The two deep infections requiring removal of the prosthesis were most regrettable. The six superficial infections were annoying but not so serious.

To these seventy-seven complications should be added the postoperative deaths. There were nineteen deaths occurring in the first thirty days (8.33 per cent of the 228 cases). However, many of the deaths in the second and third thirty-day periods occurred while the patients were still in the hospital, and therefore must be considered as influenced by the operative procedure. To be critical of the operation, perhaps all should be included. There were seven deaths in the second thirty-day period and eight deaths in the third. If these are all classed as postoperative deaths, there would then be thirty-four (14.91 per cent) of the 228 cases. If these were added to the seventy-seven complications, we would have a total of 111 cases in which some form of complication occurred. This would be misleading, however, since some of the complications occurred in patients who also died.

Of the 228 patients reported, twenty-three were not followed, and two were not rated because of lack of information. This leaves 203 patients. Of these, seventy-one are dead, but thirty-one survived long enough following surgery to be included in the results. We have, therefore, 163 cases for more detailed study and grading.

In sixty-three (38.65 per cent) of the 163 patients, the results were classed *excellent* or *good*, and are, I believe, very good results. In thirty-seven the results were classed *fair;* these should probably also be included in the satisfactory group because we are dealing with such old people. If this is done, we have 100 patients (61.35 per cent) of the 163, in whom the results may be considered satisfactory. However, of the patients who were ambulatory at the time of fracture, it is doubtful if any were restored to the same functional capacity that was present prior to the fracture. There are a few in whom the result is classified *still on crutches* who are not too far in the postoperative period and who may be quite good later; at this time however all those reported *still on crutches* are classed as unsatisfactory.

Since it was the opinion of some of us that there would be fewer complications, more rapid recovery, and perhaps a better result if an anterior approach were utilized, a comparison of the anterior with the posterior incision was made (Table I).

There are ninety-five patients in whom the anterior approach was utilized. The average hospital stay was 28.21 days. Postoperative complications occurred in twenty-three patients, most of which were minor. There were, however, six dislocations, three fractures of the femur, and three infections. One of these was deep, requiring removal of the prosthesis. Results in the sixty-seven patients available for grading in whom an anterior incision was used were found to be: nine *excellent*, twenty-one *good*, and nine *fair*, or a total of thirty-nine results (58.2 per cent) that could be considered satisfactory.

There were 128 patients in whom the posterior incision was utilized. The average hospital stay was 45.64 days. Complications occurred in forty-six patients; again, most were minor, but the major complications were: four dislocations and five infections, one of which was deep and required removal of the prosthesis. In the ninety-three patients available for grading, the results were: nine *excellent*, twenty-three *good*, twenty-eight *fair*, or a total of sixty (64.5 per cent) that could be considered satisfactory.

Actually these two groups compare rather well. There was a significantly shorter period of hospitalization in the group in which the anterior approach was used. Complications were about the same except that there was a higher death rate in the first thirty days when the posterior approach was used. In the group in which the posterior incision was used there was a higher percentage of satisfactory results, primarily because of the inclusion of those graded as *fair*.

When we examine the results in regard to the type of prosthesis used, it appears that the long-stem metal type of prosthesis is slightly better than the other types, in that there were more patients in whom the results were excellent or good following use of this type. Regarding the question of the best method of postoperative management, I expected to find that one after which no postoperative fixation was used would give the least complications, but no one procedure stands out. It appears that the prosthesis has stood up well during the time of this study (the average follow-up was 15.1 months).

In 1939 a report was made by this committee on the use of internal fixation in the treatment of femoral-neck fractures[1]. A comparison of these two series gives us a yardstick for evaluation of the status of the prosthesis.

The average age of the patients in whom a prosthesis was used is greater, as is the death rate in the first thirty days. In the present series there was a shorter period of postoperative fixation and postoperative hospitalization, with a much earlier ambulation record.

Infection occurred more frequently following insertion of a prosthesis but the difference is not great. The percentage of satisfactory results is about the same. We must remember, however, that none of the hips of the patients in whom a prosthesis was used could be considered normal; certainly very few patients could be considered to have as good a hip as that obtained when union of the fracture occurs without the complication of aseptic necrosis or degenerative arthritis.

It seems, therefore, that the insertion of a prosthesis is not much more hazardous nor the postoperative complications much greater than is internal fixation.

Long-term follow-up studies may in the future suggest that there is a place for this method of treatment in a younger age group. At the present time we feel that the results are not as good as those obtained when union of a fracture of the neck of the femur occurs in good position, without complications. Therefore this method should not be used in any patient in whom there is a reasonable chance of obtaining union—provided that the general condition of the patient is such that a reconstructive procedure may be carried out, should internal fixation fail.

No clear superiority of operative or postoperative management is demonstrated in the evaluation of these cases.

SUMMARY

This review suggests that the insertion of a prosthesis in the treatment of fresh femoral-neck fractures is not appreciably more hazardous to the patient than internal fixation. In carefully selected patients it allows more rapid ambulation and a shorter period of hospitalization and postoperative disability.

Concerning the type of prosthesis, although results with the various models are not greatly dissimilar, there is evidence that the metallic long-stem variety is best.

I had expected the anterior type of operative procedure to be much superior; however, there was little difference between the two. The percentage of satisfactory results was greater in patients in whom the posterior approach was used; but there were fewer complications, a shorter period of hospitalization, and fewer deaths in the first thirty days with the anterior approach.

Repair of the capsule, when possible, is advisable. Although the figures do not show striking differences, there is an indication that the avoidance of postoperative fixation, in addition to early ambulation, results in fewer complications.

The use of a prosthesis may be indicated purely for relief of pain in the severely debilitated patient; for the most part, however, to justify an operation of this magnitude, one prerequisite should be a reasonable chance that the patient may soon again become ambulatory.

There does seem to be a place for the replacement prosthesis in the management of fresh femoral-neck fractures. Since the length of time a prosthesis may be expected to function cannot be determined by this study, we feel that the circumstances in which this procedure is presently indicated are as follows:

1. In the old patient who is a relatively poor risk and in whom it seems likely that only one surgical procedure will be possible.

2. When early ambulation is essential and the condition of the patient makes the use of a walker or crutches unlikely.

3. In patients who have Parkinson's disease or spastic paralysis.

4. When a satisfactory reduction and fixation of the fracture cannot be obtained even by open operation.

1. Conwell, H. E.: Treatment of Fractures of the Neck of the Femur by Internal Fixation. Report of the Fracture Committee of The American Academy of Orthopaedic Surgeons. J. Bone and Joint Surg., **21**: 483–486, Apr. 1939.

DISCUSSION

Dr. Frederick R. Thompson, New York, N. Y.: This paper shows careful handling of a difficult subject. The data come from several sources. I agree with the rigid criteria for the classification of the cases into excellent, good, fair, and poor. It is interesting to note that, of the 163 cases on which a final rating was available, there are only nineteen excellent results, an incidence of 12 per cent. This low percentage should give pause to anyone contemplating the immediate use of a prosthesis as a treatment for a fresh fractured neck of the femur. Even at the advanced age of seventy-five, which is the average of his group

of cases, a Smith-Petersen nailing should achieve better than 12 per cent excellent results. I am sure that, with the passage of time, many of the good results would advance to the excellent group. When the intramedullary long-stem type of prosthesis is placed in an acetabulum containing good cartilage, as is usually the case following a fresh fracture of the femoral neck, it is difficult to understand why the vast majority of these patients are not pain-free. Why are some hips painful? I am unable to answer this question. I believed for some time that the motion of the stem within the medullary cavity was a prime cause of discomfort. As time passed, however, I found to my surprise that these painful hips became painless although many still retained the toggle motion of the prosthetic stem within the medullary cavity. Other patients in whom there was considerable motion of the stem have denied ever having pain. Motion of the stem, therefore, does not seem to be characteristic of either a good or a bad result, although I still prefer to see naturally develop the hooklike bone projection around the lower tip of the stem to keep it immobile against the lateral wall.

A prosthesis is rarely indicated; its primary use, in my opinion, is still as a salvage procedure. I do believe there are special instances, however, when its primary use is justifiable, but these instances are infrequent. I agree with Dr. Reynolds that it is indicated in spastic hemiplegia and in Parkinson's disease. It is also indicated, in my opinion, in fractured femoral necks occurring in patients with chronic multiple rheumatoid arthritis, in patients with severe mental disease in whom shock therapy should not be interrupted following fracture, and in certain tumors of the bone. It is not indicated in the vast majority of instances in which one simply says the patient is old. I am sure that many older persons are safer and better treated by a closed reduction and a Smith-Petersen nailing than by any prosthesis. I cannot help but believe that a surgeon who is proficient in putting in one of these prostheses finds the Smith-Petersen nailing an infinitely simpler and safer procedure.

Prosthesis breakage has been minimized by further technical developments of the manufacturer so that only seven Vitallium breakages have been reported of some 35,000 of all types sold. In spite of this, metal fatigue will occur if the prosthesis is at work in the body long enough.

I disagree with Dr. Reynolds that a prosthesis is indicated when satisfactory reduction and fixation of the fracture cannot be obtained at operation. Many fractures, incompletely reduced and nailed, go on to satisfactory union without aseptic necrosis. In particular, I am speaking of the Pauwel Type III fracture which is never an indication for a prosthesis in my opinion. In our hands the instance of non-union has not been high in this group. Most of our trouble has occurred with the so-called easier types of fractures. In clinics in which there is an incidence of non-union above 20 per cent there should be developed a better technique for the proper reduction of the proximal fragment in the valgus position before fixation. There is no doubt that early mobilization and ambulation of the patient probably contribute a great deal to the slipping of the fragment. A little more bed rest and walking with crutches without weight-bearing for a longer period of time is preferable to a secondary prosthesis operation.

DR. JOSEPH S. BARR, BOSTON, MASSACHUSETTS: This report, representing the combined efforts of the members of the Committee on Fractures and Traumatic Surgery, is of great interest to every surgeon who treats hip fractures. That the members of the committee treated 228 fractured hips by prosthesis in four years indicates dissatisfaction with internal fixation.

Knowing the total number of intracapsular fractures in that time from which were selected these 228 for prosthetic treatment would give some idea how radical or how conservative was the selection of patients. Probably the cases reported represent chiefly those not suitable for internal fixation, that is, fragmented, irreducible fractures in the older age group of patients. If so, it is significant that the percentage of good results in prosthetic replacement is almost identical with that of good results in the unselected intracapsular fractures treated by internal fixation. This means that the poorest risks are taken and made equal to the average. That I think speaks rather well for the future of this method when it is also considered that the committee members were learning how to use prostheses during this time. The comparison of anterior and posterior approaches was, I think, not too valid. I suspect that at least three types of approaches were used. There is the anterior or Smith-Petersen approach. Second, the posterolateral approach as described by Gibson. In this approach the glutaeus medius and glutaeus minimus are reflected from the trochanteric crest but the capsule is exposed and incised anteriorly or anterolaterally; this is not really a posterior approach. It is an anterior or an anterolateral approach and I think probably should be grouped with the Smith-Petersen approach as the anterior type if there are going to be only two types.

The true posterior approach is through the glutaeus maximus fibers and through the short external rotators which are posterior. The dangers of postoperative dislocation are probably much less with the true posterior approach than with the Gibson or Smith-Petersen approach and that has been true in everyone's hands. I believe the insertion of a prosthesis in a freshly fractured hip can be done through any one of these three incisions.

I feel that the Gibson approach gives the best exposure with the least trauma. It can be modified for any vicarious incident and can be used for a major or a minor exposure. The data presented do not allow definite conclusions as to the relative merits of the seven types of prosthesis used, but the intramedullary-

(Continued on page 910)

A Study of Experimental Trauma to the Distal Femoral Epiphysis in Rabbits—II*†

BY J. ALBERT KEY, M.D. (DECEASED), AND LEE T. FORD, M.D., ST. LOUIS, MISSOURI

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Three types of experimental trauma to the lower femoral epiphysis of twenty-nine rabbits were carried out earlier by the authors and this work was published in 1956 [1].

It was felt by the authors after completing the experiment that more work needed to be done along this line. Accordingly, five additional sets of experiments were planned and carried out. In these, as before, rabbits three to four weeks of age were utilized. The distal portion of the right femur was operated upon in each case after the knee region had been prepared with a depilatory and cleansed with septisol, followed by tincture of merthiolate. The knee was draped and, with sterile operating-room technique, the various experiments were carried out. Ether anaesthesia was utilized following a sedative dose of intravenous nembutal. Barbiturate anaesthesia was not found satisfactory in these young animals since the dosage was found to be inconsistent with body weight.

Animals in the earlier experiment were divided into Groups I, II, and III, so animals in this experiment were divided into groups and designated Groups IV through VIII.

In one group of animals (Group IV), after exposure of the knee joint, a small recess was made one-eighth inch deep by means of a drill point in the intercondylar portion of the femur. A small Vitallium nail (one-half inch long) was then driven across the epiphysis and epiphyseal cartilage of the femur. The nail was so placed that its head was below the level of the articular cartilage. It did not seriously damage the joint, but it remained in contact with the epiphysis and was constantly across the epiphyseal cartilage during the period of growth.

In another group of animals (Group V) the knee joint was opened, the patella was dislocated, and the lateral one-half of the periphery of the distal femoral epiphysis was curetted. This curetted portion extended just through the thickness of the cortex and included the periosteum and perichondrium in the region of the epiphyseal cartilage. The amount of cartilage removed was three or four millimeters in thickness.

In another series (Group VI), the lateral aspect of the distal portion of the femur was exposed in the same manner and a small gouge was used to raise a flap of bone. This flap or tongue consisted of a portion of bone from the epiphysis, a portion of the epiphyseal cartilage, and a portion of the lateral cortex of the metaphysis. This flap was wedged outward slightly and bone wax was placed under the flap to lessen bone union of the flap in its bed.

In still another series of animals (Group VII) the distal portion of the femur was exposed and a one-eighth inch hole was drilled directly across the metaphysis from the lateral to the medial side just proximal to the epiphyseal cartilage, care being taken not to damage the cartilage. A mixture of three parts of bone wax and one part of croton oil was placed in the hole. It was hoped that this chemical would serve as an irritating substance and might stimulate activity of the epiphyseal cartilage and thus increase growth of the epiphysis.

In the last series of animals (Group VIII) the distal portion of the femur was exposed and a one-eighth inch drill hole was made in the lateral condyle of the femur only, the hole

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FIG. 1

FIG. 2

Fig. 1: (Group IV) Rabbit #37. Anteroposterior and lateral roentgenograms of the right and left femora in which a small Vitallium nail was placed across the epiphysis twenty-two weeks earlier. The femur operated upon was one millimeter longer than the left (control) femur. The tibia on the side operated on was two millimeters longer than the control tibia.

Fig. 2: (Group V) Rabbit #13. The lateral half of the periphery of the distal epiphysis in this femur was curetted twenty weeks previously. Marked valgus deformity resulted and the femur operated upon is 1.4 centimeters shorter than the control femur. The tibia on the side operated upon is one millimeter longer than its control.

being made distal to the epiphyseal cartilage and care being taken not to damage the cartilage. A mixture of bone wax and croton oil was then placed in the drill hole. It was hoped that this might again serve to stimulate activity of the epiphyseal cartilage and thus increase growth of the lateral portion of the distal end of the femur.

A considerable number of animals were lost because of anaesthesia problems; however, there were forty surviving animals. These were sacrificed at intervals varying from seventeen to twenty-one weeks following operation. The tibiae, fibulae, and femora were dissected free. Roentgenograms were made and measurements in length were made from these films. Following this, the distal portion of the femur and the knee joint were examined

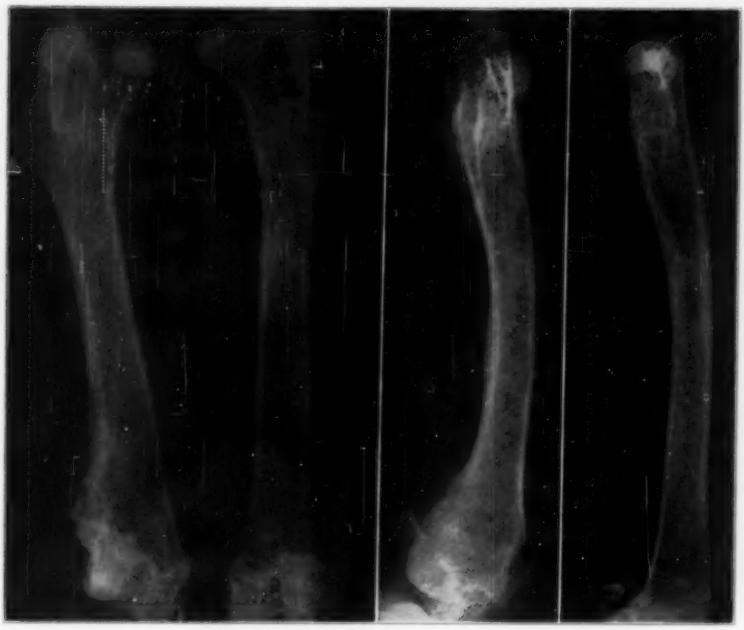

FIG. 3

(Group VI) Anteroposterior and lateral roentgenograms of the right and left femora. Nineteen weeks previously a flap of bone including epiphyseal cartilage was raised from the lateral aspect of the distal portion of the femur and held elevated with bone wax. Valgus deformity resulted but only two millimeters of shortening is present as compared with the control femur.

grossly. Microscopic sections were prepared of the distal portion of the control femur and the femur operated on. The right femur was utilized for the experiment and the left femur served as a control in each animal.

ROENTGENOGRAPHIC EXAMINATION

Group IV (Vitallium Nails across Epiphysis)

These femora were normal on roentgenographic examination except for the presence of the small Vitallium nail in the distal portion of the femur crossing the epiphyseal line of the right femur in each case (Fig. 1).

Group V (Partial Curettement)

In these animals the outer one-half of the periphery of the epiphyseal cartilage had been curetted. As expected, valgus deformity of each femur with some new-bone formation and irregularity of the lateral side of the distal portion of the femur was present to a varying degree (Fig. 2).

Group VI (Elevated Flap of Epiphyseal Cartilage)

In this series of animals in which a flap was raised, roentgenograms showed valgus deformities of the distal end of the femur with sclerosis and irregularity at the lateral aspect of the distal portion of the femur (Fig. 3). While the bone was elevated laterally in several animals, no definite exostoses were seen.

Group VII (Drill Hole in Metaphysis with Bone Wax and Croton Oil)

In these femora a hole had been drilled across the metaphysis and the mixture of

FIG. 4

Anteroposterior and lateral roentgenograms of the femora operated upon and control femora in which a hole was drilled in the metaphysis seventeen weeks previously and was filled with bone wax mixed with croton oil. There is broadening of the femur with anterior angulation and new-bone formation with a sterile abscess cavity in the center of the femur. The femur operated upon is 0.8 centimeter shorter than the opposite. The bone near the condyle is a normal sesamoid.

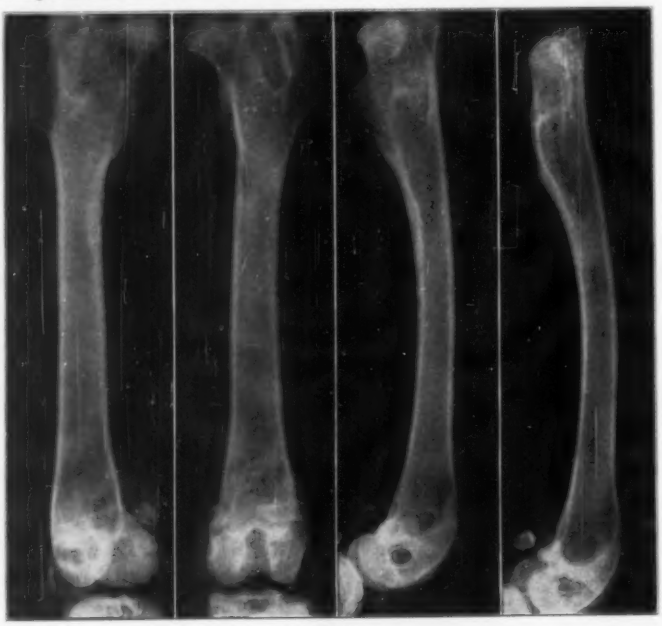

FIG. 5

(Group VIII) Anteroposterior and lateral roentgenograms of the femora operated upon and control femora. Seventeen weeks previously a small hole was drilled in the lateral condyle of the femur and bone wax with croton oil was placed in the hole. No significant deformity is present and the femur operated upon is one millimeter longer than the control femur. The tibiae were of equal length.

TABLE I

RABBITS WITH PARTIAL CURETTEMENT (GROUP V)

Animal No.	Femoral Shortening (*Centimeters*)	Tibial Growth Discrepancy (*Centimeters*)
4	0.7	0
5	0.9	0
8	0.7	0.1 overgrowth
11	0.9	0.2 shortening
12	1.1	0.3 overgrowth
13	1.4	0.1 overgrowth
17	0.7	0.2 shortening
21	0.9	0.1 shortening
31	0.6	0.2 overgrowth
34	0.2	0
38	0.3	0
46	0.2	0
Average (Shortening)	0.7	

bone wax and croton oil had been inserted. There was a very marked reaction in the bone to the noxious substance. There was formation of a large involucrum around the drill hole and, in most femora, the site of the drill hole was near the middle of the shaft of the femur as the epiphysis grew away from it (Fig. 4). In most femora the shaft was very broad and expanded around the region of the drill hole.

Group VIII (Drill Hole in Lateral Condyle with Bone Wax and Croton Oil)

Except for one animal, roentgenographic changes in these femora were not marked (Fig. 5). In one animal, a varus deformity resulted with some broadening of the metaphysis and slight cortical thickening on the medial side.

GROSS EXAMINATION AND MEASUREMENT

Group IV (Vitallium Nail across the Epiphysis)

The knee joints in these animals on the side operated upon appeared normal. The small hole made in the cartilage in the condylar notch had healed over with fibrocartilage and was almost invisible.

On an average, the five femora operated upon were equal in length to the control

TABLE II

RABBITS WITH AN ELEVATED FLAP OF EPIPHYSEAL CARTILAGE (GROUP VI)

Animal No.	Femoral Shortening (*Centimeters*)	Tibial Overgrowth (*Centimeters*)
7	0.4	0.1
14	0.2	0
16	1.0	0.2
18	0.7	
23	1.4	0.6
25	0.4	0.2
33	0.9	0
35	1.2	0.2
Average (Shortening)	0.8	

TABLE III

RABBITS WITH DRILL HOLE IN METAPHYSIS WITH BONE WAX AND CROTON OIL (GROUP VII)

Animal No.	Femoral Shortening (*Centimeters*)	Tibial Growth Discrepancy (*Centimeters*)
3	0.8	2.2 shortening
9	0.6	0.1 overgrowth
10	1.5	0.1 overgrowth
26	1.1	0.2 overgrowth
27	1.4	0.2 overgrowth
36	0.8	0.1 overgrowth
42	2.0	
43	2.0	0.1 overgrowth
45	2.3	0.4 shortening
Average (Shortening)	1.4	

femora. Two of the femora operated upon were one millimeter longer than those on the control side and two were one millimeter shorter than the controls; one femur was exactly equal to its control. The animals were sacrificed an average of twenty-one weeks following surgery.

Group V (Partial Curettement)

Valgus deformities were consistently present in this group. Scarring of the knee joint with degenerative change was present in varying degree in each of the knees operated upon.

The twelve femora in this group showed an average shortening of 0.7 centimeter (7.1 per cent); the average control femur was 9.9 centimeters in length (Table I). The difference in femoral shortening varied from 0.2 to 1.4 centimeters.

These animals were sacrificed an average of nineteen weeks following surgery.

Group VI (Elevated Flap of Epiphyseal Cartilage)

Valgus deformity of the distal portion of the femur with varying degrees of degenerative arthritic changes in the knee was a consistent finding. In one case a lateral dislocation of the patella was present and in another there was almost a 90-degree valgus deformity.

The average shortening of the eight femora in this group measured 0.8 centimeter (8 per cent) in over-all length, not considering the valgus deformity. Shortening varied from 0.2 to 1.4 centimeters (Table II).

This group of animals was sacrificed an average of nineteen weeks following surgery.

TABLE IV

RABBITS WITH DRILL HOLE IN LATERAL CONDYLE WITH BONE WAX AND CROTON OIL (GROUP VIII)

Animal No.	Femoral Growth Discrepancy (*Centimeters*)	Tibial Growth Discrepancy (*Centimeters*)
1	0.1 shortening	0.1 shortening
6	0.3 shortening	0.2 overgrowth
19	0.1 overgrowth	0
32	0.1 shortening	0.2 overgrowth
39	1.3 shortening	0
40	0.2 shortening	0
Average (Shortening)	0.4	

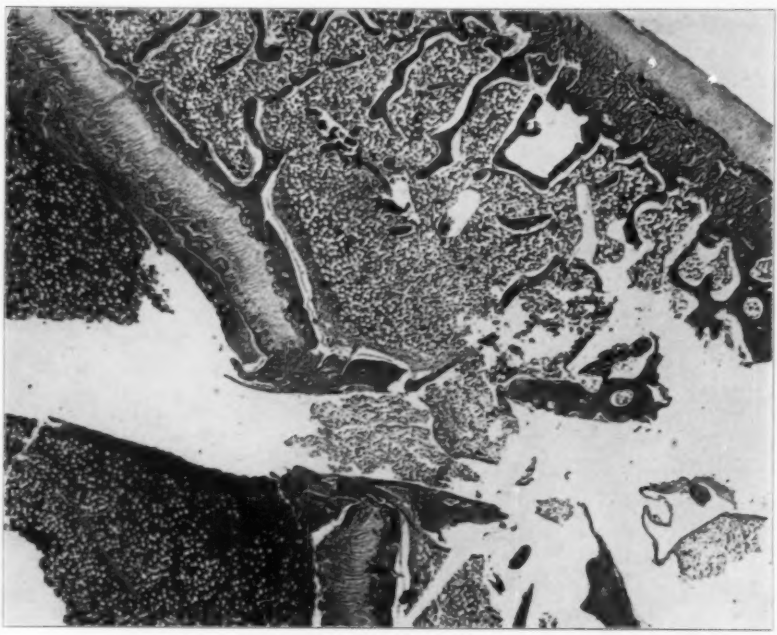

FIG. 6

Photomicrograph of the center of the epiphyseal cartilage of the distal portion of the femur where Vitallium nail had crossed. New bone formed across the interrupted ends of the epiphyseal cartilage but there was no interference in growth.

Group VII (Drill Hole in Metaphysis with Bone Wax and Croton Oil)

The nine femora in this series showed broadening, shortening, and distortion of the shaft of the femur, appearing in several cases like osteomyelitis. In three cases fracture had occurred. Moderate arthritic changes in the knee joints were present in several and considerable scarring in the periosteum was noted about the broad, deformed femur.

Average shortening was 1.4 centimeters (14.7 per cent) of the over-all length. The shortening varied from 0.6 to 2.3 centimeters (Table III).

Group VIII (Drill Hole in Lateral Condyle with Bone Wax and Croton Oil)

Slight to moderate arthritic changes were noted in the knee joints of several of these animals. Scarring over the region of the lateral condyle was usually present.

There were six surviving animals in this group. Average shortening of the femur operated upon was 0.4 centimeter (3.2 per cent) (Table IV). In one animal the femur operated on was 0.1 centimeter longer than the control. The discrepancy varied from +0.1 to −1.3 centimeters.

An average of seventeen weeks elapsed from surgery to sacrifice.

MICROSCOPIC FINDINGS

Group IV

A defect in the epiphyseal plate could be seen; however, the epiphyseal cartilage appeared to be intact up to this defect (Fig. 6). There was usually some new-bone formation along the edges of the nail defect, but since measurements showed no effective shortening, this had not resulted in any interference with growth.

Group V

In most cases the epiphyseal plate was no longer present. In several animals some of

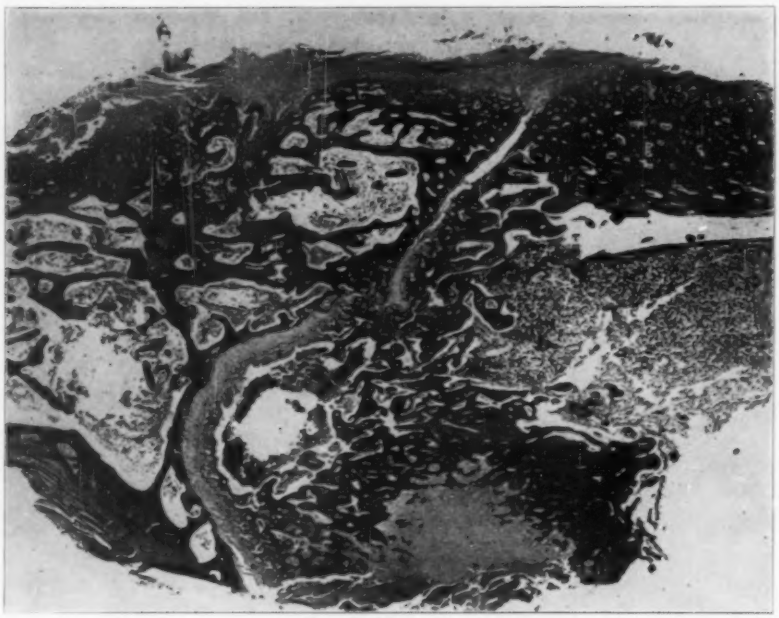

FIG. 7

Photomicrograph (×6) of the lateral condyle of the femur through which a gouge had passed and raised a flap of bone including the outer portion of the epiphyseal cartilage. The broader epiphyseal cartilage is that which remained intact while the thin band adjacent to it is the remnant of cartilage which was elevated with a flap of bone.

the medial portion of the epiphyseal cartilage was still present. There was usually considerable sclerotic new bone on the lateral aspect of the former plate in the region of the curettement.

Group VI

In most animals no epiphyseal cartilage was present on the side operated upon. In two animals, remnant strands of epiphyseal cartilage cells were seen (Fig. 7). Much sclerotic bone was present about the distal portion of the shaft of the femur. In one animal some remnant epiphyseal cartilage was present but it was offset at the site of the injury to the plate by the gouge. Bone on either side of the cut in the epiphyseal plate was healed and sclerotic. Epiphyseal cartilage cells in the site of the flap were irregular and the remnant epiphyseal plate was thin.

Group VII

In most cases some remnant of the epiphyseal cartilaginous plate was present; this was usually distorted or was thin and flat. Sections of the sclerotic portion of the femur at the site of the drill hole showed, in some cases, a mass of detritus (remnant bone wax) with fibrous tissue and reactive granulation tissue about it, in addition to the reactive and sclerotic cortical bone (Fig. 8).

Group VIII

In these sections the epiphyseal cartilaginous plate was either closed completely or was almost closed with some residual cartilage cells present near the center.

DISCUSSION

In Group IV it was surprising that there was no effective interference with growth of

FIG. 8

High-power view showing an area in the center of the bone with a remnant of bone wax present in the cavity with necrotic bone nearby. Fibrous tissue lines the cavity with reactive bone surrounding the fibrous wall.

the femur by leaving the small Vitallium nail in place. This suggests that it may be possible to place metallic materials of a reactive type across the epiphysis, possibly two different materials, and stimulate growth of the epiphysis. Further experiments to study this aspect are planned. In the earlier experiments [1], drilling a one-eighth inch hole across the same epiphysis and filling it with gelfoam resulted in an average 8 per cent shortening of the femur.

In the partial curettement of the distal femoral epiphysis (Group V), the anticipated result was obtained in that there was interference of growth of the lateral aspect of the epiphyseal cartilage while the medial portion continued to grow almost normally. This resulted in valgus deformities with irregularity and new-bone formation about the lateral condyle of the femur in the region of the curettement.

By elevation of a flap of the lateral aspect of the femur (Group VI), including a portion of the epiphysis and epiphyseal cartilage and then placing bone wax under this flap, it was expected to have some exostoses develop. Such was not the case. Interference of growth of the lateral portion of the epiphysis did result. This was expected.

Placing an irritating chemical mixed with bone wax in a drill hole in a metaphysis (Group VII) failed completely to produce any stimulation of growth in the adjacent epiphyseal plate. It is true that as growth did occur the epiphyseal cartilage moved farther away from the irritating chemical. The substance placed in the drill hole in the bone did result in a sterile osteomyelitis.

A similar reaction did not occur when a small amount of the bone wax with the croton oil mixed with it was placed in a drill hole in the lateral condyle of the femur only. The reason for this is not known; possibly the irritating chemical was absorbed by the synovial membrane of the knee joint and thus removed from the bone. There was, however, no stimulation of growth by placing the irritating chemical near the epiphyseal plate.

CONCLUSIONS

1. In addition to the three types of experimental trauma carried out upon the lower femoral epiphysis of rabbits and reported earlier, five additional types of experimental trauma have also been carried out.

2. Placing a small Vitallium nail across the epiphysis does not appear to interfere with growth of the bone.

3. Curetting the lateral portion of the periphery of the epiphyseal cartilage results in a valgus deformity and moderate shortening of the femur.

4. The elevation of a flap of bone including a portion of the epiphyseal cartilage will likewise result in some interference of activity of that portion of the epiphysis and will result in a valgus deformity with moderate shortening of the femur.

5. Placing bone wax and croton oil in a metaphysis of the femur results in shortening of the femur with an osteomyelitic reaction in the bone, but does not stimulate growth of the bone.

6. Placing bone wax and croton oil in a drill hole in the lateral condyle of the femur likewise does not stimulate growth of the epiphyseal cartilage.

7. The epiphyseal cartilage in rabbits is normally sensitive to trauma.

1. Ford, L. T., and Key, J. A.: A Study of Experimental Trauma to the Distal Femoral Epiphysis in Rabbits. J. Bone and Joint Surg., **38-A**: 84-92, Jan. 1956.

Fluorescence of Tetracycline Antibiotics in Bone*

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Selective deposition of exogenously derived materials in the skeleton represents not only a potential health hazard, but also, and for identical reasons, provides an excellent means whereby histological evidence of specific biological processes in bone may be obtained. This is particularly true of radioactive atoms of the physiologically important elements calcium and phosphorus, of certain of the unphysiological radioactive nuclides, especially those of the transuranium series, and of some organic dyes, specifically those related to alizarin [2, 8]. Recently [7], data have been presented which indicate that antibiotics of the tetracycline series (tetracycline, chlortetracycline, and oxytetracycline) also specifically localize in bone. The present study constitutes an amplification of these latter observations and tends to suggest that the tetracycline drugs may be employed *in vivo* as effective histological indicators of newly proliferated bone tissue.

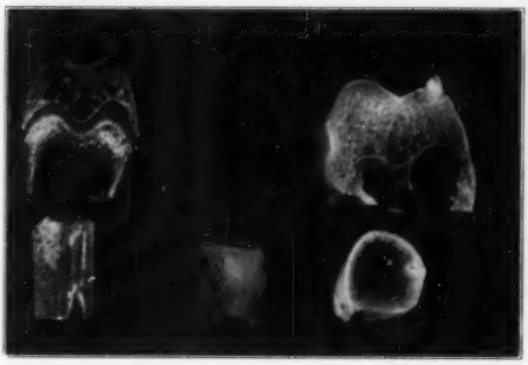

FIG. 1

FIG. 2

Fig. 1: Ultraviolet-light photographs showing the localization of tetracycline in young bone (*left*) and adult bone (*right*) of rabbits. The lower portion of the femur and diaphysis of the femoral shaft is shown twenty-four hours after an intraperitoneal injection of fifty milligrams per kilogram of body weight. In the young animal, weighing one kilogram, intense induced yellow-gold fluorescence appears in the subepiphyseal portion of the metaphysis and in the diaphysis. The epiphyseal cartilage shows only normal bluish autofluorescence in ultraviolet light. The zone of provisional calcification (gray in this photograph) shows normal blue-gray autofluorescence. The control bone from a two-kilogram rabbit in the center shows blue autofluorescence in all portions. In the adult bone on the right from a three-kilogram rabbit, a cream-colored type of fluorescence is diffusely distributed throughout the bone. (Reprinted by permission from "Bone Localization of the Tetracyclines" by R. A. Milch, D. P. Rall, and J. E. Tobie: Journal of the National Cancer Institute, **19:** 87–93, 1957.)

Fig. 2: Localization of tetracycline can be seen in adult (*top*) and young (*bottom*) rat femora, twenty-four hours after an intraperitoneal injection of fifty milligrams per kilogram of body weight. In ultraviolet light, the subepiphyseal zone of new-bone formation in the metaphysis of the adult rat, in which the epiphyses do not close, shows intense induced fluorescence; the distribution of induced fluorescence within the bones elsewhere is the same as that observed in other animals (Fig. 1).

* Presented in part at the meeting of the Northeast Orthopaedic Club, National Institutes of Health, Bethesda, Maryland, June 21, 1957.

MATERIALS AND METHODS

Tetracycline, chlortetracycline, and oxytetracycline* were administered to human subjects and laboratory animals under a variety of different clinical and experimental conditions.

Sprague-Dawley rats weighing eighty to 150 grams and New Zealand white rabbits weighing one to three kilograms were used in most experimental studies, after it had been initially established that there were no detectable differences in organ and tissue localization among various species of mice, rats, guinea pigs, rabbits, and dogs. Animals were maintained on standard laboratory diets and were given water *ad libitum*. In most studies, intraperitoneal doses of each of the tetracyclines at the level of fifty milligrams per

FIG. 3

Low-power (×80) ultraviolet fluorescence photomicrograph demonstrating localization of tetracycline in the ossification center of the sternum of a rat. The section is undecalcified. The ossification center itself (*right*) presents induced yellow-gold fluorescence as does the proximal portion of the sternum (*left*). The intervening cartilage, however, (*center* and *far lower right*) shows normal blue autofluorescence. Gray-blue autofluorescence is present in the nuclei of the cells of cartilage.

kilogram of body weight were administered. Doses from 0.1 milligram per kilogram to 200 milligrams per kilogram of body weight were given by subcutaneous, intramuscular, and intravenous injections and by mouth for special studies.

Rats were sacrificed at intervals of from thirty minutes to ten weeks for tissue-specificity studies after a single intraperitoneal injection of antibiotic. Rats and CA F_1 mice were employed in studies of the rate at which bone localization occurred and were sacrificed at approximately twenty-second intervals after the start of an intravenous injection of fifty milligrams per kilogram of body weight. Time-dose studies were performed on

* Tetracycline (achromycin), lot numbers 7–6211 and 6–6030, and chlortetracycline (aureomycin), lot number 7–6212, were supplied by Lederle Laboratories Division, American Cyanamide Company, Pearl River, New York. Oxytetracycline (terramycin), lot number WBW-517361, was supplied by Charles Pfizer and Company, New York, N. Y.

rats weighing 140 grams. A four-hour interval following intraperitoneal injection of tetracyclines in doses of 0.1 to 200 milligrams per kilogram of body weight was arbitrarily selected as the time for comparison and the lower portion of the femur was arbitrarily selected as the bone to be examined. Doses of fifty milligrams per kilogram of body weight were administered to animals employed in studies of the effect of age on the bone localization of the fluorescent material.

Experimental bone defects were produced in the diaphyseal portion of the femur in rabbits weighing two kilograms. The animals were anaesthetized by ether inhalation and, with aseptic technique, a defect through one cortex was produced by means of a clinical dental burr. The wounds were closed primarily and no immobilization was employed; the animals were sacrificed at weekly intervals after operation.

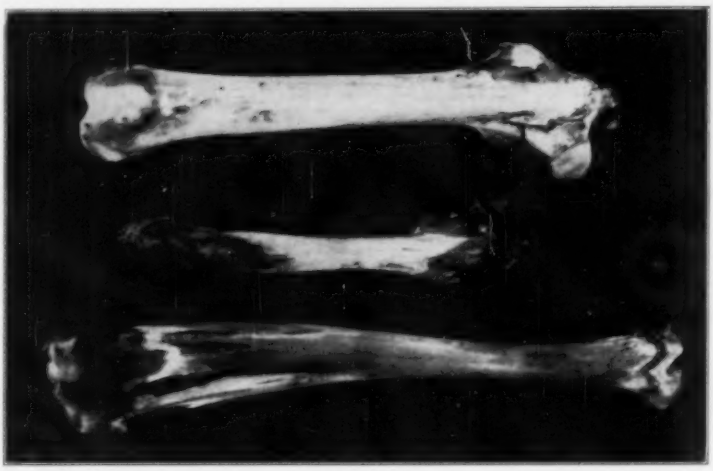

FIG. 4

Photograph made in ultraviolet light of rabbit bones after a single intraperitoneal injection of fifty milligrams per kilogram of body weight of tetracycline. The upper bone, from a rabbit weighing three kilograms, shows cream-colored fluorescence characteristic of adult animals. The center bone from a rabbit weighing one kilogram shows the typical pattern observed in young animals. The lower bone is the tibia of a rabbit given a single intraperitoneal injection of tetracycline six months prior to sacrifice. A brilliant band of induced fluorescence can be seen at the upper end of the bone at a considerable distance from the growing zone. A similar band is observed at a shorter distance from the distal end of the bone. These appear to represent areas in which the fluorophor was deposited at the time of administration. A diffuse pattern of induced fluorescence, appearing more cream-colored in ultraviolet light than intensely yellow-gold, is localized in the diaphyseal portion of the femoral shaft. The autofluorescent regions elsewhere represent bone laid down subsequent to the time of tetracycline administration.

Tissues from human subjects were obtained either at operation or at autopsy, were stored in the fresh state at approximately −10 degrees centigrade and were then examined. Tissues from experimental animals were removed immediately after sacrifice. The specimens were examined grossly under a 125-watt ultraviolet-light source (3660 angstroms *) and were then stored at −10 degrees centigrade for subsequent microscopic examination. No alterations were noted either in the intensity or the localization of bone fluorescence with storage at this temperature, even for prolonged periods of time.

Fresh, frozen sections of undecalcified bone were cut on a rotatory microtome by the utilization of a Model DT-31 Techni-Freeze † or a Cryostat ‡. When the Techni-Freeze

* Model SC-5041 ultraviolet light, Hanovia Chemical and Manufacturing Co., Newark, New Jersey.
† Scientific Products Division, American Hospital Supply Co., Evanston, Illinois.
‡ Harris Refrigeration Co., Cambridge, Massachusetts.

was employed, the bone was frozen with freon, sections were cut and floated on water, and the sections applied to an ordinary glass slide. When the Cryostat was used, the bone was frozen at −10 degrees centigrade, sections were cut approximately fifteen micra thick and placed directly on the glass slide. In both methods, the slides were mounted in glycerin-gelatin (1:1) and covered with ordinary glass cover slips. Only occasional sections were satisfactory for histological examination owing to fragmentation of the specimen and numerous efforts were usually made before adequate sections were obtained.

The sections were examined under darkfield illumination with a Leitz Ortholux microscope. The light source was a water-cooled 1000-watt General Electric AH-6 high-pressure mercury-arc lamp; a six-millimeter UG-1 filter was introduced into the light

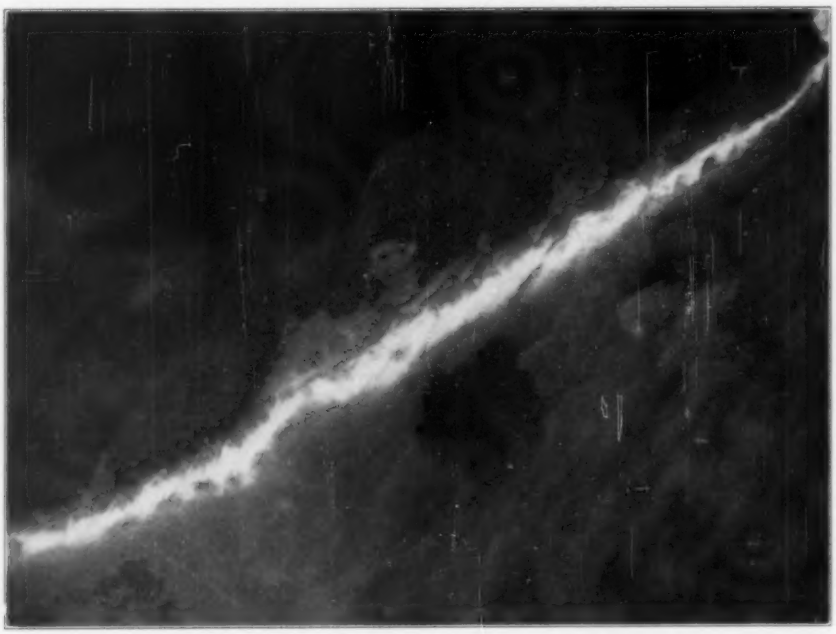

FIG. 5

Low-power (×80) photomicrograph made in ultraviolet light shows fluorescence in a longitudinal section of the rib of a rat. The section is undecalcified. The animal was given a single intraperitoneal injection of fifty milligrams per kilogram of body weight of tetracycline ten weeks prior to sacrifice. A zone of induced yellow-gold fluorescence (white in this photograph) can be seen within the substance of the rib. The overlying bone, which is blue in ultraviolet light and partially fragmented in this section, shows normal autofluorescence (gray in this photograph).

path to provide maximal excitation of the bone sections at a wave length of 3650 angstrom units.

Photomicrographs were made with a thirty-five millimeter Leica camera with a Wratten 2B filter in the photographic eyepiece. Black-and-white exposures were obtained over time intervals of thirty to sixty seconds with Kodak Tri-X (TX-135) safety film, which was developed in Promicrol for thirty minutes and then fixed in a routine manner. Enlargements were printed on F-3 Kodabromide paper and developed in Dektol.

RESULTS

1. *Tissue Distribution of Fluorescence*

Following parenteral administration of the tetracyclines, brilliant yellow-gold fluorescence was readily detectable in tissues in which localization had occurred; only

normal bluish autofluorescence, which was most apparent in blood vessels, cartilaginous extremities of the long bones, hyaline cartilage of the trachea and axial skeleton, and the brain, was detected in other tissues. The induced fluorescence was in striking contrast to normal autofluorescence in every instance.

Diffuse distribution of the induced fluorescence was apparent for a period usually not exceeding twelve to twenty-four hours after parenteral administration in all of the animal species observed. After this time interval, all soft tissues were noted to resume their pre-injection autofluorescence; the induced fluorescence persisted, however, in both long and flat bones, and, in rodents, in the incisor teeth as well.

In human subjects, the induced fluorescence and autofluorescence appeared to have the same pattern of distribution as that observed in the animal species.

2. *Effect of Route of Administration*

In neither human subjects nor in laboratory animals was there any evidence whatever

FIG. 6

Low-power (×80) photomicrograph made in ultraviolet light shows fluorescence in a transverse section of the femoral diaphysis of a rabbit. This is an undecalcified section. The cambium layer of the periosteum shows intense localization of the fluorophor, whereas the fibrous layer and established bone show normal bluish autofluorescence. Osteocyte lacunae in this photograph appear whitish, but in ultraviolet light they actually appear blue.

to indicate a pattern of distribution dependent upon the route of administration of the drugs. Following intravenous injection in rabbits, in which the pelvifemoral muscles had been extirpated, and in intact rats, bone fluorescence could be detected virtually instantaneously following the beginning of an intravenous injection; in mice, too, fluorescence was readily discerned within twenty seconds of the start of an intravenous injection of tetracycline. Soft tissues presented similar fluorescence under these circumstances, but in every case, the yellow-gold fluorescence persisted in bones and progressively diminished until it was totally undetectable in the soft tissues.

3. *Effect of Dosage Schedule*

Owing to the present lack of any analytical procedure for the quantitative estimation

of the fluorophor in tissues, quantitative studies could not be undertaken. In general, however, a given dose of each tetracycline produced qualitatively identical results in each of the various animal species. A semi-quantitative estimate of the total amount of fluorophor present in the skeleton could be made in some instances and this could occasionally be graded on a 1+ to 4+ scale. By use of such a criterion, bones of rodents tended to show values in the 4+ range in contrast to the bones of humans and dogs, given an identical dose per unit of body weight, which tended to show values more toward the 2+ range.

Quite evident differences in bone localization among young and adult animals were present in all species, but this seemed apparently solely due to differences in skeletal age and not to other factors.

FIG. 7

Medium-power (×100) photomicrograph made in ultraviolet light shows fluorescence in a transverse section of the femoral diaphysis of a rabbit. This is an undecalcified section. The intense induced yellow-gold fluorescence present in the cambium layer reflects sufficient light, in this photograph, to partially obscure the normal blue-gray autofluorescence of the fibrous periosteal layer. Osteocyte lacunae immediately subjacent to the periosteal lining show induced fluorescence, which appears to be absent from the osteocyte nucleus. The lacunae located closer to the center, however, show only normal blue-gray autofluorescence.

In the human subjects, the usually employed clinical dosage schedule for adults (one to two grams per day) was quite sufficient to produce obviously detectable bone fluorescence, both grossly and microscopically, after a single day of therapy.

Striking bone fluorescence was apparent in all laboratory animals following a single parenterally administered injection of the tetracyclines in doses varying from five to 200 milligrams per kilogram of body weight. Unequivocal, minimal bone fluorescence could be detected at the lower end of the femur in rats given parenteral doses in the range of 0.25 to 0.30 milligram per kilogram of body weight. (If no difference in dosage effects between the human and animal species were assumed, these latter doses would roughly correspond to administering about twenty milligrams, or less than one-tenth the amount

present in a single commercially available tablet of the tetracycline drugs, to a human being weighing seventy kilograms.)

4. *Effect of Sex and Age on Bone Fluorescence*

In no study, either in the human or in the animal species, was there any evidence whatever to indicate direct effects of sex on the distribution of fluorescence in the skeleton. In all experiments, however, localization of the fluorophor in both endochondral and membrane bone characteristically and uniformly was quite different in young than in adult animals (Figs. 1 and 4).

In long bones, the epiphyseal cartilage plate of young animals showed only bluish autofluorescence, while the area corresponding to the zone of provisional calcification and

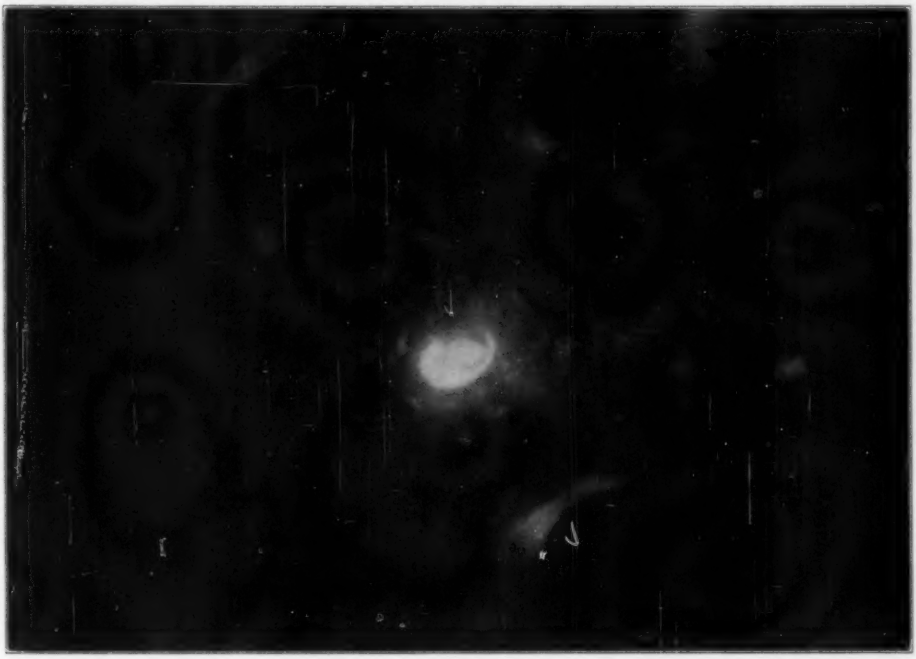

FIG. 8

Low-power (×80) photomicrograph made in ultraviolet light shows fluorescence in Haversian canals in the femur of a rabbit. This is an undecalcified section. A newly proliferated Haversian canal (*center*) shows intense yellow-gold induced fluorescence, whereas established osteons show blue autofluorescence.

of vesicular cartilaginous hypertrophy showed a light bluish-gray autofluorescence in ultraviolet light. The subjacent metaphyseal region, however, showed intense yellow-gold fluorescence as did the periosteal and endosteal surfaces of the diaphysis. Established cortical bone, on the other hand, showed only normal autofluorescence. These phenomena were observed in all animals.

In adult animals of most species, a more or less generalized type of fluorescence was observed which was different both from that of young animals and the autofluorescence of control animals. This presented a cream-colored appearance in ultraviolet light which seemed to be almost uniformly distributed throughout the long bones; only an occasional animal showed any tendency for enhanced intensity of fluorescence in the metaphyseal regions among the rabbits, dogs, and guinea pigs. In adult rats, on the other hand, in which the epiphyses do not permanently close, an intense yellow-gold band of fluorescence

was constantly observed to be present in the subepiphyseal region of the metaphysis at the same time that other portions of the bone presented a type of fluorescence characteristic of the adult animals (Fig. 2).

Centers of ossification in both the axial and appendicular skeleton showed brilliant yellow-gold induced fluorescence so long as complete ossification had not occurred. Microscopically, this was apparent in all animal species, and was best demonstrated in the upper portion of the tibia, the sternum, and the spinal column (Fig. 3).

5. *Persistence of Bone Fluorescence*

When once deposited in the skeleton, induced fluorescence was not displaced in any species for relatively prolonged periods of time. Rabbits have been observed six months after a single parenteral dose and, at sacrifice, have shown bone fluorescence in a dis-

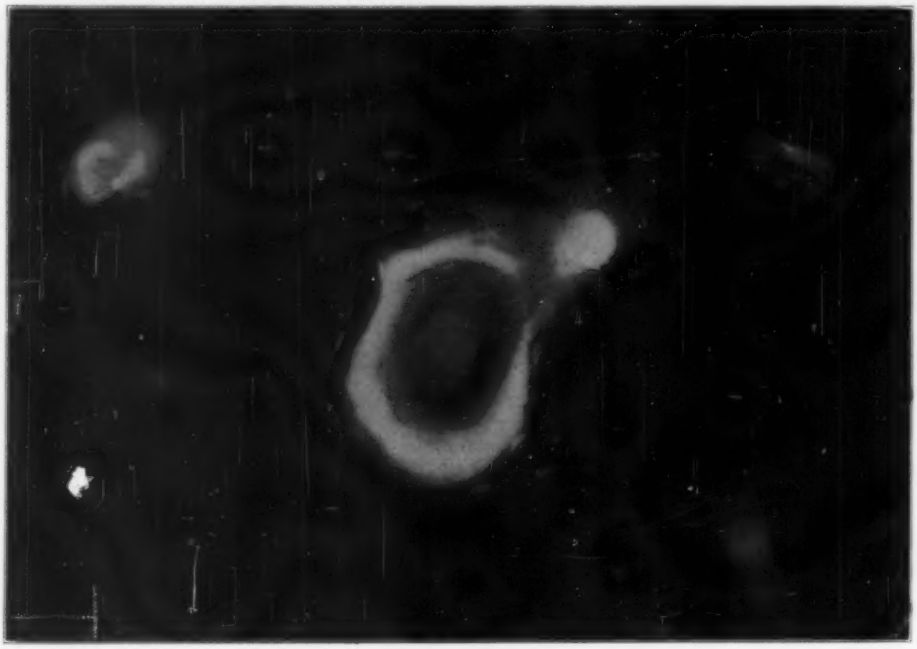

FIG. 9

Medium-power (×100) photomicrograph made in ultraviolet light shows fluorescence in Haversian canals in the femur of a rabbit. The section is undecalcified. Osteons in the center of the photographic field show intense induced fluorescence; established osteons present within the same microscopic field, however, show only autofluorescence.

tribution pattern similar to that observed in the subepiphyseal portion of the metaphysis, but at greater distances from the epiphyseal plate of young animals (Fig. 4). Other animal species have likewise shown this phenomenon. Microscopic examination of rat bones ten weeks after a single injection of fifty milligrams per kilogram of body weight of tetracycline has demonstrated apparent fixation of the fluorescent material in the bone with superimposition of more lately formed bone upon the area of induced fluorescence showing only normal autofluorescence (Fig. 5).

The precise biological half-life of the bone fluorophor, however, as with information concerning the total amount of a given dose represented by skeletal fixation, remains unelucidated at this time owing to technical and analytical difficulties. Further studies are in progress in this laboratory, however, and will be reported subsequently.

6. *Microscopic Localization of Bone Fluorescence*

Microscopically, articular and epiphyseal cartilage presented a deep blue or bluish-gray appearance in ultraviolet light, which was distinctly different from the brilliant yellow-gold induced fluorescence. Of considerable interest was the observation, also made grossly, that intense fluorescence was typically present in regions characterized by newly proliferated bone tissue, as contrasted to established bone, which showed only autofluorescence. Periosteal surfaces showed intense fluorescence which could be sharply contrasted from regions of earlier bone deposition (Figs. 6 and 7). Similarly, newly formed Haversian canals were quite readily distinguished from those that had formed earlier in the growth of the bone (Figs. 8 and 9); there was, also, constantly an abrupt delineation

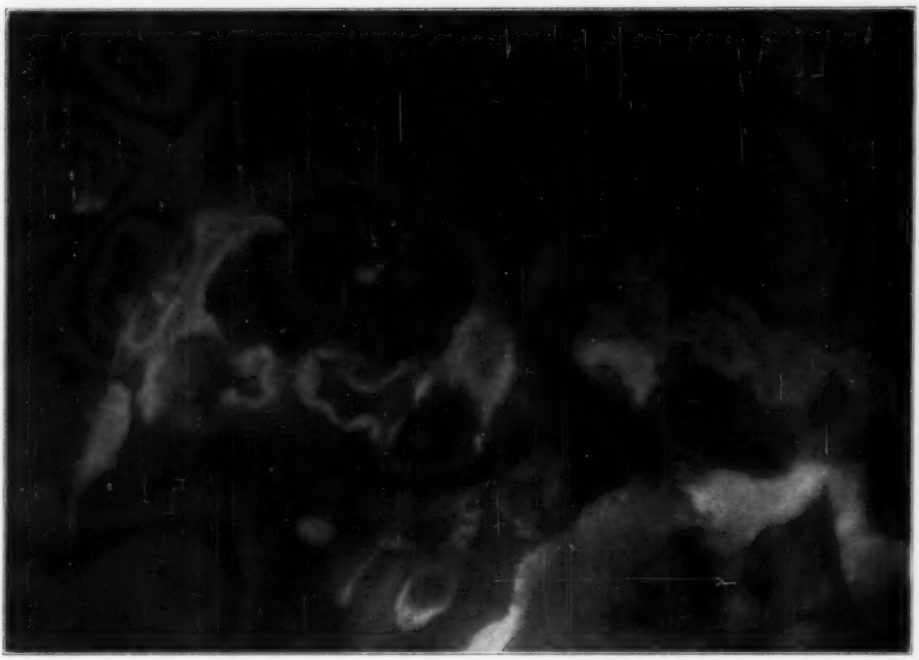

FIG. 10

Low-power (×80) photomicrograph made in ultraviolet light shows fluorescence of the subchondral portion of the articular surface of the femoral head of a rabbit weighing one kilogram. This is an undecalcified section. The cartilaginous portions of the field in ultraviolet light are deep blue in the proximal section (*top*), and gray-blue near the zone of provisional calcification. Newly proliferated osteoid seams are intensely yellow-gold and regions of established bone show normal blue autofluorescence.

between newly formed bone and zones of calcified cartilage in the junction of the epiphyseal cartilage and metaphyseal bone and at the junction between hyaline articular cartilage and subchondral, supra-epiphyseal bone (Figs. 10 and 11).

7. *Distribution of Fluorescence in Abnormal Conditions*

Following the production of drilled defects in diaphyseal bone of adult and young rabbits, the distribution pattern of fluorescence was in no way different from that observed in normal animals with the one exception that fluorescence was readily detectable in callus. Similarly, in a case of an osteocartilaginous exostosis of the fibula * in a patient to whom one gram of tetracycline had been given orally during the twenty-four hours

* Courtesy of Dr. Henry Milch, the Hospital for Joint Diseases, New York, N. Y.

preceding operation, fluorescence was readily detectable in regions of newly proliferated bone, but entirely absent from cartilaginous areas. In an osteogenic sarcoma which spontaneously occurred in an AKR mouse *, fluorescence could be detected in the osseous portions of the tumor, but was absent from other regions surrounding the osseous portions of the neoplasm (Fig. 12).

At autopsy examination of several patients to whom tetracycline had been given for variable periods prior to demise, areas of presumed new-bone growth showed intense induced fluorescence, whereas areas of established bone showed normal autofluorescence (Figs. 13 and 14).

DISCUSSION

The present observations tend to suggest that each tetracycline antibiotic localizes

FIG. 11

High-power (×160) photomicrograph made in ultraviolet light shows fluorescence of the junction of the epiphyseal cartilage and metaphyseal bone in the capital femoral epiphysis of a rabbit. This is an undecalcified section. The zone of provisional calcification presents bluish-gray autofluorescence which is precisely differentiated from the brilliant yellow-gold (white in this photograph) induced fluorescence present in regions of new-bone proliferation.

in the skeleton in a specific pattern, which is strikingly uniform in all species studied and which is apparently entirely independent of sex, the route of administration employed, and the precise dose administered. There is, however, a distinct and direct relationship between the intensity and the localization of skeletal fluorescence and the age of the animal, and hence, of the skeleton, at the time that the drugs are administered. Furthermore, skeletal localization occurs at extremely rapid rates after parenteral administration, even when remarkably small doses are employed, and, when once established in bone, fluorescence appears to remain largely unaffected for prolonged periods of time.

Unfortunately, owing to analytical difficulties, a precise, quantitative evaluation of

* Courtesy of Dr. Margaret G. Kelly, National Cancer Institute.

FIG. 12

Fig. 12: Low-power (×80) photomicrograph made in ultraviolet light shows fluorescence of an osteogenic sarcoma in an AKR mouse. The irregularly interlaced bands of abnormal bone show intense induced fluorescence limited to regions of apparent new-bone deposition.

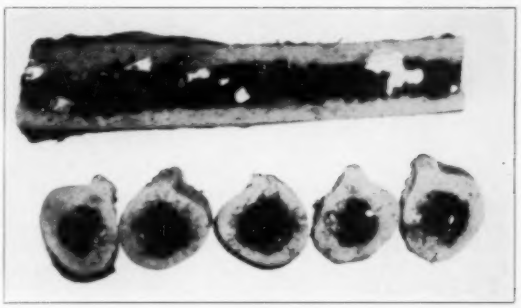

FIG. 13

Fig. 13: Longitudinal and transverse sections of the femur of a female patient with skeletal metastases from cancer of the breast. Established bone shows normal autofluorescence which is readily distinguished from areas of intense induced fluorescence which are present primarily around the periphery of the lytic metastases.

the total amount of administered compound that enters into bone and of its biological half-life when once established, remains unexplained at this time. A significant discussion, therefore, of the purely public-health aspects of skeletal localization of these compounds is untenable at this time. The biological implications, however, are manifest.

In virtually all of a continuing series of studies, it has been observed that there is a general distribution of fluorescence only in regions characterized by new-bone proliferation. It is attractive to speculate, since these are regions characterized also by excellence of blood supply, that localization occurs as if in consequence of the anatomical relationship to vascular endothelium. Clearly, surface bone, being in closest anatomical position to tissue fluids containing high concentrations of the administered compounds, would be expected to be presented with relatively greater total amounts of tetracyclines than would more internally located, and hence physiologically more inert, bone crystals. Accordingly, it might be expected that such regions would show fluorescence purely on the basis of the total amount of material deposited.

There is, however, much against this view. In the first place, tissues other than bone, such as heart, kidney, spleen, and lung, which have excellent blood supplies, do not show persistence of fluorescence, whereas bone does. Secondly, in experimental bone defects, where callus and established bone are in intimate anatomical relationship, it is only the new bone that presents fluorescence following tetracycline administration. Thirdly, in areas where new bone is formed essentially within an area of cartilage, such as in ossification centers, there is a constant sharp gross and microscopic junction between the two types of tissue. Finally, at both the junction of the epiphyseal cartilage and metaphyseal bone and in the region of subchondral bone near articular cartilage, fluorescence can be detected only in true bone, despite the fact that the vascular supply of the submicroscopic region is presumably identical and that morphologically identical apatite crystals exist

FIG. 14

Low-power (×80) photomicrograph made in ultraviolet light shows fluorescence of the region present in Fig. 13. This section is partially decalcified. Interlaced bundles of tissue which appear as fibrous-tissue strands in routinely stained preparations show localization of induced fluorescence in ultraviolet light, thus suggesting their identification as the fibrous-tissue constituent of true membrane bone [6].

both in the bone and in the calcified cartilage. Data obtained here and elsewhere [6] tend to suggest that a similar situation occurs in cases of membrane-bone formation within and around skeletal metastases from cancer.

In view of observations that calcium ions will bind tetracyclines both *in vitro* and *in vivo* [4, 9, 11] and that the present data on tetracycline distribution are essentially identical to those reported for alizarin by Cameron and for radioactive calcium by Arnold and associates, it becomes attractive to speculate that the naphthacenecarboxamide nucleus of the tetracyclines in some manner binds to calcium in regions of physiologically available bone. Findings presented here, however, relevant specifically to the various junctions of cartilage and bone in the body, tend to militate somewhat against this view. It is difficult to comprehend the mechanisms involved when a tissue-like calcified cartilage, which has a

known calcium density greater than newly formed bone [10], does not show fluorescence in the extremely small anatomical area within which true bone does show fluorescence.

It would seem more likely, in terms of the classic study of Robinson and Cameron that calcium alone is not responsible for the fixation of the tetracyclines, but rather, that a more complex interfacial interaction, possibly between the tetracycline nucleus, calcium, and the protein matrix of newly formed bone, is involved. Recent studies from these laboratories [5] indicating that bone fluorescence arises in consequence of the deposition of chemically unaltered tetracycline, which is apparently capable of being bound to a butanol-extractable peptide fraction in bone, would tend to lend additional credence to a hypothesis based almost solely on anatomical findings.

SUMMARY AND CONCLUSIONS

Antibiotics of the tetracycline series (tetracycline, chlortetracycline, and oxytetracycline) were administered to human subjects and laboratory animals under a variety of clinical and experimental conditions. The drugs were administered orally to human subjects in the usually employed clinical schedule (one to two grams per day) and by the oral and all parenteral routes to male and female animals of varying ages in doses from 0.1 to 200 milligrams per kilogram of body weight. In all circumstances, brilliant yellow-gold induced fluorescence was detectable in ultraviolet light (365 millimicra) following administration of each of the drugs.

In the animals the induced fluorescence was apparent in diffusely distributed tissues, with the exception of brain, almost instantaneously following intravenous injection and within thirty minutes of intraperitoneal administration. It persisted for approximately six hours in all tissues and was undetectable grossly in soft tissues twelve to twenty-four hours later. Long and flat bones, however, and the incisor teeth of rodents as well, showed persistence of the fluorophor for prolonged periods of time. Striking fluorescence was observed after doses in the range of fifty to 200 milligrams per kilogram of body weight and unequivocal, minimal fluorescence could be detected with doses in the range of 0.2 milligram per kilogram of body weight.

Localization and intensity of the bone fluorophor, which appears to be chemically unaltered drug, was entirely unaffected by the route of administration, by the dose schedule employed, or by the sex of the individual. Microscopically, localization in bone appeared to be limited to regions of true new-bone proliferation (mineral and matrix phases) in both adult and young animals and in both normal and certain pathological conditions. This localization accounted for the gross pattern observed in young animals and for the characteristic cream-colored type of induced fluorescence typical of adult animals. No differences in localization could be detected between all species observed, including humans, except on the basis of the relative physiological age of the particular bone region examined.

It is suggested that bone fluorescence, following administration of the tetracycline antibiotics, arises from a complex interfacial interaction which presumably involves the four-ringed naphthacenecarboxamide nucleus of the tetracyclines, calcium, and the organic matrix of newly proliferated bone.

The investigative, public health, and therapeutic implications of this precise localization of tetracyclines in bone would seem to be obvious.

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DISCUSSION

Report of Committee on Fractures and Traumatic Surgery

(*Continued from page 886*)

stem prosthesis, such as the Fred Thompson and the Austin Moore models, seems to be slightly superior. We have used the Austin Moore prosthesis at the Massachusetts General Hospital since March 1952. There have been no failures from breakage or foreign-body reaction. There have been dislocations, sepsis, and the other complications which were reported. We agree with the recommendations concerning the indications for use of a prosthesis and hope that the committee will continue to collect and analyze their data based on their experience.

Hamstring Transplant for the Prevention of Calcaneocavus Foot in Poliomyelitis*

BY HARRY E. EMMEL, M.D., AND JOHN F. LE COCQ, M.D., SEATTLE, WASHINGTON

From the Seattle Orthopaedic and Fracture Clinic, Seattle

Calcaneocavus foot occurs frequently in the growing child after poliomyelitis. Many surgical procedures have been developed to correct the deformity after it has become well established, but little has been done to prevent the deformity from occurring. Any method that would restore the function of plantar flexion of the foot after the calf muscles have been paralyzed in poliomyelitis would tend to prevent the deformity from developing, providing it exerted sufficient pull into the heel cord.

Calcaneocavus foot develops rapidly after paralysis of the calf muscles, particularly when the dorsiflexors of the foot and toes and the flexors and intrinsic muscles of the foot have remained strong. Several potent factors work to bring about this deformity:

1. The force of gravity alone pulls unopposed against the Achilles tendon, the muscles of which have been paralyzed.

2. The calcaneal epiphysis (a traction epiphysis) requires for its normal development the constant tugging pull of the Achilles group of muscles. Without this stimulating influence the calcaneus becomes oddly shaped, shortened, and falls into a cavus position. This results in a shortening of the lever arm of the calcaneus decreasing its efficiency and reducing the amount of pull that can be transmitted into the heel by whatever muscle power remains.

3. The unopposed power of the dorsiflexors of the foot influences the development of this deformity. The active power of these dorsiflexors forces the heel into a vertical position to the ground; then, in order for the fore part of the foot to reach the ground, the intrinsic muscles of the foot must shorten so that the metatarsals are against the weight-bearing surfaces. This creates further cavus deformity of the foot and shortening of the intrinsic muscles and plantar fascia.

FIG. 1

A typical fully developed calcaneocavus deformity.

* Read at the Annual Meeting of the Western Orthopedic Association, San Francisco, California, October 14, 1954.

FIG. 2

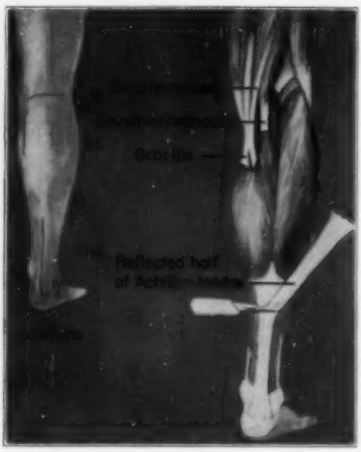

FIG. 3

Fig. 2: View of the side of the calf and thigh. This indicates the insertion of the gracilis and semitendinosus in the region of the anterior medial tibialis.

Fig. 3: Posterior views of the calf showing the skin incisions and detached thigh muscles. The method of sagittally cutting the Achilles tendon is shown.

With these factors acting unopposed on the foot over a period of years, the foot becomes more and more deformed as the child grows. This results in a typical heel-walker type of gait. This is an ungainly walk, as well as an inefficient one. Without the power to plantar flex the foot, there is a serious handicap in the take-off in walking.

Present concepts in handling this disability have resulted in the policy, in general, of waiting until the child is old enough for a stabilizing operation—usually a triple arthrodesis or a panarthrodesis at the age of ten to twelve years. These procedures are accepted and are useful in correcting the deformity after it has become well established.

Tenodesis operations have been used in an attempt to prevent the deformity and have been somewhat successful. For the most part, however, the tendons stretch and do

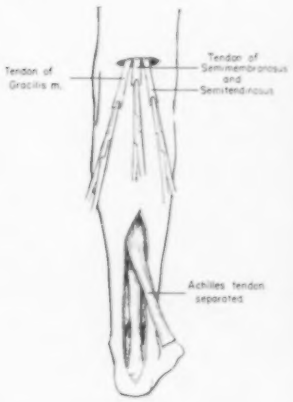

FIG. 4

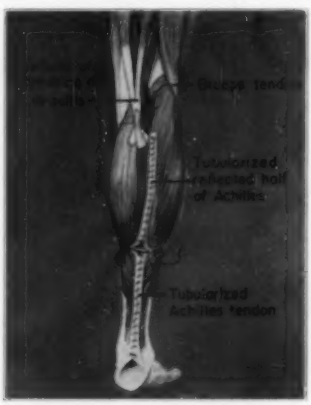

FIG. 5

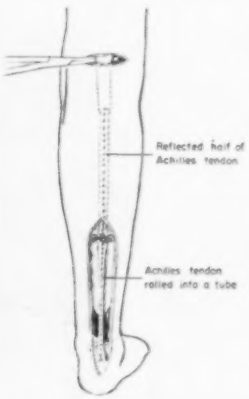

FIG. 6

Fig. 4: Diagrammatic drawing of the gracilis, semitendinosus, and semimembranosus being swung posteriorly to the back of the calf while the half of the cut Achilles tendon is being reflected upward.

Fig. 5: Drawing of the hook-up, showing the tubularized Achilles tendon reflected upward for the attachment with the three thigh muscles.

Fig. 6: Drawing shows how the three muscles are brought out from under the popliteal fascia to be inserted subcutaneously and connected with the reflected Achilles tendon.

not hold against the strong pull of the opposing muscles. In some instances the tendons do not grow at an equal rate with the bone and a deformity of equal proportion develops in some other direction.

In conjunction with the various types of stabilizing operations, all available inverters and everters which have sufficient power can be transplanted into the calcaneus with varying degrees of success in supplying power to the heel cord. Frequently however, the inverters and everters are paralyzed. This leaves the surgeon without available good muscle power to transplant into the calcaneus except perhaps one of the dorsiflexors through the interosseous membrane. This has been done with reasonable success.

The purpose of this presentation is to propose a method by which active muscle

FIG. 7-A

FIG. 7-B

FIG. 7-C

Figs. 7-A, 7-B, and 7-C: This patient is able to stand on his toes bearing full weight.

pull can be transmitted into the calcaneus when the calf muscles have been paralyzed. It is certain that unless sufficient active muscle pull can be maintained on the heel cord during the growing years, the typical calcaneocavus deformity will develop.

It is, therefore, proposed that some muscle in the thigh be used to transmit the active pull to the Achilles tendon. The semitendinosus and gracilis muscles insert far down on the anterior medial border of the tibia and send a long slip of tendinous tissue into the deep fascia of the calf. Normally these tendons bowstring somewhat across the popliteal space when the knee is flexed beyond 30 degrees, but up to that point of flexion they are held firmly against the popliteal space by the tough and inelastic transverse fibers of the popliteal fascia. These tendons can be detached from their insertion and a portion of the tendinous slips into the deep fascia can be taken with them. They can then be swung posteriorly and subcutaneously down the back of the calf for a considerable distance.

The heel cord can be cut sagittally and swung upward subcutaneously so that it can be attached to the two hamstring muscles with sufficient overlapping for firm suturing.

The incisions are usually three in number; sometimes four are made. The first incision is made over the insertion of the medial hamstrings and gracilis to detach them from their insertion at the tibia. A second incision is made over the popliteal space transversely so that these detached tendons can be swung posteriorly and reinserted by sliding them subcutaneously down the back of the calf. The third incision is made parallel to the Achilles tendon usually on the medial side, the tendon being exposed from its insertion upward

TABLE I

FINDINGS IN PATIENTS IN WHOM HAMSTRINGS WERE TRANSPLANTED INTO HEEL CORD FOR CALCANEOCAVUS

Age at Onset of Poliomyelitis	Age at Operation (*Years*)	Muscle Evaluation before Surgery	Muscles Used in Transplant	Years of Follow-up and Additional Procedures	Range of Motion of Ankle Joint	End Result
1. C.G. 1 yr.	3	Complete paralysis of calf muscles, posterior tibialis; typical heel-walker	Semitendinosus, gracilis, and semimembranosus	2; Grice bone block	Equal to other side	Momentarily takes complete weight on fore part of foot; foot well balanced; beginning to show growth of calcaneal epiphyses
2. M.G. 10 mos.	2	No calf-muscle power; 1 inch of atrophy; early calcaneocavus deformity	Semitendinosus, gracilis, and semimembranosus	4; Grice bone block	Equal to other side	42-pound push with fore part of foot; no further calcaneocavus; foot is stable; momentarily able to take entire weight on fore part of foot
3. S.D. 4 yrs.	5	Complete paralysis of calf muscles; weak peronaei; early calcaneocavus deformity	Semitendinosus, gracilis, and semimembranosus	4; transplant anterior tibialis to lateral border of foot; Grice bone block	Unable to dorsiflex foot above 90 degrees	49-pound push with plantar flexion; will need a stabilization operation later and correction of varus deformity; some cavus deformity
4. V.W. 10 yrs.	11	Complete paralysis of calf muscles; no cavus deformity, but some varus deformity	Semitendinosus, gracilis, and semimembranosus	2½; triple arthrodesis; transplant anterior tibialis to lateral border of foot	Equal to other side	Able to bear momentarily full weight on toes and able to push steadily 70 pounds in plantar flexion; no further calcaneocavus

5. K.P. 5 yrs.	7	Complete paralysis Achilles group, left calf muscles; weak anterior tibialis; increasing calcaneocavus	Semitendinosus, gracilis, and semimembranosus	2½	Equal to other side	Able to walk on tiptoes; no further cavus deformity; 1-inch shortening, left leg
6. J.T. 6 yrs.	8	Practically no power in Achilles group, right calf	Semitendinosus, gracilis, and semimembranosus	3	Dorsiflexion blocked at 90 degrees	Transplanted hamstring became adherent to popliteal-space tissues and failed to prevent cavus deformity
7. S.C. 18 mos.	3	Complete paralysis Achilles group; moderate calcaneocavus	Semitendinosus, gracilis, and semimembranosus	3	Equal to other side	Able to exert 12-pound pull on Achilles tendon; calcaneocavus arrested
8. M.C. 4 yrs.	8	Complete paralysis calf muscles; fairly advanced calcaneocavus	Semitendinosus, gracilis, and semimembranosus	3	Equal to other side	Able to exert 20-pound plantar flexion; no further calcaneocavus
9. V.B.	30	Complete paralysis, but no deformity; painful heel	Semitendinosus, gracilis, and semimembranosus	4	Equal to other side	30-pound push-off with fore part of the foot; no further painful heel; improved walking rhythm
10. P.J.P. 18 mos.	4	Complete paralysis Achilles group; calcaneocavus	Semitendinosus, gracilis, and semimembranosus	2; subtalar arthrodesis for valgus deformity	Equal to other side	No further deformity

to just above its musculotendinous junction. The Achilles tendon can be cut sagittally in half turning upward one half of the tendon. The two halves should be folded into a round tubelike tendon and sutured by fine catgut in order to make them as smooth gliding structures as possible. The upper end of the split tendon should be secured with mattress sutures in the corners in order to prevent further tearing of the tendon at the musculotendinous junction.

It will be found that there is adequate tendon to suture, with usually one and one-half to two inches overlapping of the ends of the hamstrings and the portion of the Achilles tendon which has been turned upward. The semimembranosus is also detached and incorporated into this three tendon hook-up. Of course, it is not as long as the gracilis and semitendinosus, but it supplies considerably more power than the other two. Suturing should be done with the knee flexed to about 25 degrees, and with the foot in plantar flexion. The limb is immobilized in a toe-to-groin cast in this position for a period of six weeks.

After six weeks, a posterior splint is used for three weeks during rehabilitation. Exercises of the foot, ankle, and knee can be done in the tub with the splint off, and practice walking is possible between parallel bars and with crutches. The ability to plantar flex the foot can be observed over as long a period as a year.

The objective of this procedure is two-fold.

1. To prevent the deformity by supplying an active pull into the Achilles tendon during the growing years and up to the time a proper type of stabilization operation can be done. It is intended that the power of these muscles will prevent the deformity by opposing the pull of the dorsiflexors and intrinsic muscles of the foot, and also by supplying a required pull on the traction epiphysis of the calcaneus, so that this bone will develop more normally.

2. When triple arthrodesis has been done, if needed, and a relatively normal lever-arm relationship of the calcaneus has been re-established, it has been shown that this operation will supply useful power of plantar flexion in take-off. In three patients, it was decided that the biceps femoris muscle would be used instead of the semimembranosus because of the added power of this muscle.

It is felt that the ideal case for this procedure would be in a patient who had: (1) strong medial hamstrings or strong biceps, (2) complete paralysis of the Achilles group of muscles, but good stability of the lateral stabilizers (the short and long peronaei and the posterior tibialis, (3) good extensors of the toes and the anterior tibialis muscle, (4) a good quadriceps. These qualifications would be ideal, but it is difficult to find a patient in whom all these requirements are met. Most of our operations have been done on patients who failed to meet one or two of these requirements.

In one patient the connection separated as a result of a fall soon after the cast was removed. This was not determined at the time. In the time that elapsed, the strong medial hamstrings atrophied. The result has been classified *poor* for this reason. Poor judgment was used in timing the operation with a triple arthrodesis which had to be done because of the marked deformity which had developed. Corrective bone surgery on the foot should be done first.

Twenty operations have been done by the authors. The ages of the patients ranged from two to ten years at the time of surgery, except for a woman thirty years old. In this patient, the procedure was employed for relief of a painful heel and to improve walking rhythm. This was successful. Ten patients have had adequate follow-up. The average follow-up since surgery in these ten is three years. In all of the ten, the semitendinosus, gracilis, and semimembranosus were used as motor muscles to attach to the reflected heel cord. In many of the more recent cases, the biceps tendon has been used instead of the semimembranosus with encouraging early results because of its greater power. In all patients, further calcaneocavus deformity has been prevented except in Case 6 (Table I).

In this patient the transplant became adherent. This operation does not preclude the necessity for a stabilization operation at a later date, when adequate osseous development of the foot permits. However, in these cases, the architecture of the foot has been adequately preserved so that less bone has to be sacrificed in order to stabilize the foot.

SUMMARY

An operation was developed to prevent the formation of calcaneocavus deformity in growing children after poliomyelitis involving the calf muscles. Twenty operations have been done; ten of these patients have had an adequate follow-up (Table I). We believe that in selected cases of calf-muscle paralysis this procedure will prevent calcaneocavus deformity from developing in the growing child. We have also demonstrated that considerable power of plantar flexion of the foot can be developed. We have used combinations of any three of the muscles in the back of the thigh, namely, the semitendinosus (for its length of tendon), the gracilis, and the semimembranosus, or the biceps femoris muscle for additional power. We believe the biceps is an ideal muscle to include in this tendon transplant because of its excellent power and the fact that it is a one-joint muscle in part due to the short head having its origin on the femur.

NOTE: The authors wish to thank Robert J. Johnson, M.D., Anatomy Department, University of Washington, for his helpful suggestions, and Charles L. Lowman, M.D., Orthopaedic Hospital, Los Angeles, California, for his comments.

Bone Agenesis

A Case Involving the Carpus and Tarsus

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Medical Corps, United States Army

From the Orthopaedic Surgery Service, Irwin Army Hospital, Fort Riley, Kansas

This case of bone agenesis was found in a woman, twenty-six years old, first seen in the medical clinic with a complaint of *grand mal* seizures. Epilepsy had developed in the patient when she was fourteen, but the disease had been well controlled with dilantin and phenobarbital until her last pregnancy.

FIG. 1

FIG. 2

A review of systems was considered normal with the exception of locomotion. The patient had not walked until she was four and one-half years old and had always had weakness of her wrists and hands.

Family history indicated that the patient was the third of five siblings, of whom none had notable anomalies except the patient and a brother with a heart murmur. A maternal uncle had convulsions. The

FIG. 3-A

FIG. 3-B

husband's family history revealed one individual who is a dwarf, another with congenital absence of an ear, and one with epilepsy.

The patient was a white female, four feet and eleven inches in height, pale, edentulous, and with graying hair. She appeared older than her stated age. Her head was disproportionate in size to her trunk and limbs. The large calvarium had an increased anteroposterior diameter, with prominence of the frontal region and recessive orbital areas.

Roentgenographic skull studies demonstrated no evidence of intracranial ossification; however, there was marked development of the frontal sinuses. It was noted that both upper extremities became cyanotic under tourniquet pressures greater than 100 millimeters of mercury. An auscultatory blood pressure was unobtainable but peripheral pulses were good.

Laboratory examination indicated that the hemoglobin, white blood count, non-protein nitrogen, serum calcium, serum inorganic phosphorus, and alkaline phosphatase were within normal limits. A roentgenogram of the chest was negative.

The patient had functional use of all extremities. She held her hand in volar flexion when at rest (Fig. 1). The distance from the proximal phalanges to the radius was proportionally short. There was a normal range of motion of both carpal joints. The only subjective disability was lack of strength; the patient could wash dishes, crochet, and mop floors, but had difficulty lifting her children. On inspection, the feet resembled corrected club feet (Fig. 2). The patient walked with a stilted gait and the entire foot was abducted distal to the tarsal joint. There was only minimal limitation of tarsal-joint motion.

The patient had had three pregnancies. The male had an anomalous tarsus bilaterally and required a short-leg brace on the left lower extremity for ambulation (Fig. 3-A). He was four years old, but no carpal ossification centers were visible on roentgenograms (Fig. 4). A younger female had died in April 1957, and ne-

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FIG. 4

cropsy had established a diagnosis of congenital toxoplasmosis. The third and oldest child, by another father, apparently is normal.

The incidence of this type of bone agenesis is not known by the authors. The etiology is problematical. The family history and the continuation of the agenesis from mother to son would suggest a genetic etiology.

Hemangiopericytoma of the Lower Extremity

A Case Report

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A hemangiopericytoma is a rare soft-tissue tumor which was first definitely separated from the group of vascular tumors in 1942 by Murray and Stout[1,2]. They were able to show by tissue-culture methods that the epithelioid cell of the glomus tumor was identical with Zimmermann's pericyte—a modified smooth-muscle cell with long processes which wraps itself about a capillary and serves to change the caliber of its lumen. This tumor did not fit the criteria set up for hemangioendothelioma because the blood vessels were

FIG. 1

Anteroposterior and lateral roentgenograms of the right knee show no evidence of bone involvement.

lined by normal endothelium and the tumor cells were gathered outside of, but closely applied to, the reticulum sheath. Murray and Stout assumed that these cells which gathered outside the reticulum sheaths of the vessels were probably neoplastic pericytes. Definite proof of this theory is lacking, but Stout[3] stated "whether or not the name hemangiopericytoma is proper and acceptable, the existence of such a group of tumors as an entity can hardly be denied."

A hemangiopericytoma differs from the glomus tumor which it closely resembles by not having the characteristic organoid arrangement or rich nervous complement. It has a wide distribution throughout the body, involving both soft tissue and bone. It is an infiltrating tumor instead of being encapsulated and causes little or no pain. The pericytes of the hemangiopericytoma may be elongated, while those of the glomus tumor are always rounded in ordinary histological preparations. Most of all, a truly malignant glomus

FIG. 2

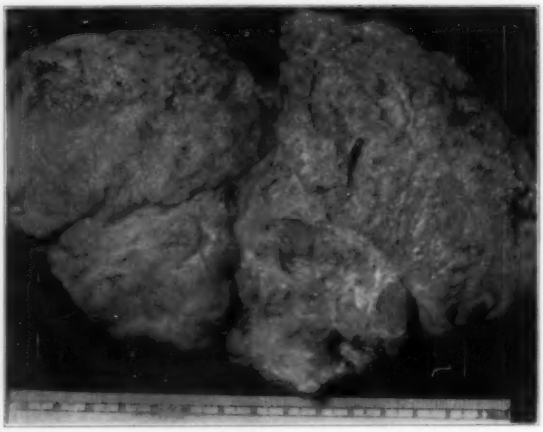

FIG. 3

Fig. 2: Femoral arteriogram shows an extremely vascular tumor. Evidence of arteriovenous malformation or aneurysm is present.

Fig. 3: Photograph of the gross specimen shows a partially encapsulated lobulated tumor weighing 430 grams.

tumor is unknown, while hemangiopericytomata are known to metastasize.

Stout [4] described 197 cases of hemangiopericytoma whose distribution was about equal between external soft tissues and internal tissues and bone. They were about equally distributed between sexes and were reported as occurring in all age groups. Of the ninety-eight cases involving external tissues, fourteen metastasized. Of these, twelve were lesions of the lower extremities; nine involved the thigh; two, the leg; and one, the foot. Of the ninety-nine cases involving the internal tissues, nine metastasized. These involved the respiratory tract in one case, mediastinum in two, retroperitoneal tissue in five, and gastrointestinal tract in one. Three cases occurred in bone, none of which metastasized.

Histologically, it is impossible to differentiate the malignant from the non-metastasizing tumors. Stout [4] stated that in almost all of his cases which metastasized, mitosis was rare or absent. The location of the tumor deep in the tissues of the lower extremity, retroperitoneum, and mediastinum should make one suspicious of malignancy.

C. C., a white man, sixty-eight years old, was admitted to the Barnes Hospital on June 22, 1948, with the diagnosis of Baker's cyst. Six years prior to admission he had injured the back of his right knee by a direct blow while mounting a horse. There was intermittent pain and swelling in the right popliteal space until about two years before admission, when a steady increase in the size of the swelling as well as an increase in pain was noted. Because of the pain and swelling, he had not been able to work. The pain was described as a drawing sensation with radiation to the outer side of the calf.

The pertinent physical findings were limited to the right lower extremity. There was a fullness in the popliteal space, and the superficial veins in this area were dilated. Palpation revealed a soft but distinct non-flocculant, non-tender, pulsating mass, found after resection to be over fifteen centimeters in length, attached to the deep tissues, but not attached to the skin. There was no evidence of infection. Auscultation revealed a bruit. The leg was not oedematous. Both posterior tibial and dorsalis pedis pulses were present, and there were no neurological or motor changes in the foot. Further examination of the knee revealed slight effusion, crepitation of the patella, and atrophy of the quadriceps. There was nearly full extension, but flexion was limited to 90 degrees.

Because of the pulsation, thrill, and bruit, a diagnosis of aneurysm was entertained. An arteriogram was then made by injecting twenty cubic centimeters of 75 per cent diodrast into the right femoral artery (Fig. 2). This revealed an extremely vascular tumor. As the laboratory tests were all within normal limits, and the roentgenograms of the chest and the right knee (Fig. 1) were normal, we were unable to make a diagnosis. A biopsy was performed.

At biopsy, what appeared to be a well encapsulated mass was found to have enormous blood vessels

all about. The biopsy specimen was reported as being a low-grade fibrosarcoma. Because it was not known with certainty whether or not the tumor was malignant, it was decided that local resection should be attempted in spite of the obvious vascularity of the mass and its unfavorable location. With a tourniquet, and by means of a Z-type incision, the mass was exposed. The vessels had the appearance of a Medusa head. Both tibial and peroneal branches of the sciatic nerve were adherent to the capsule but not incorporated in the tumor. These were dissected free and retracted. The popliteal artery was displaced by the tumor but could

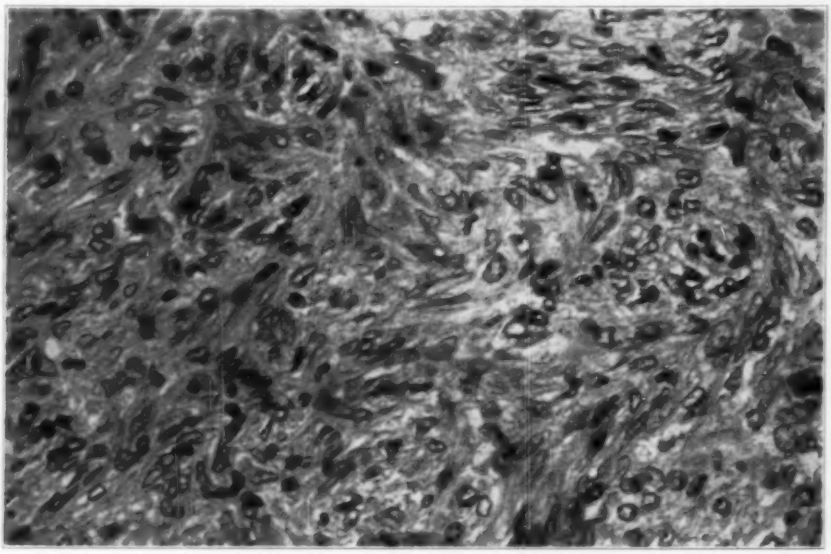

FIG. 4-A

Photomicrograph of hemangiopericytoma showing a vascular tumor composed of large masses of cells with oval vesicular nuclei. Note uniform cells, lack of mitotic activity, and absence of necrosis (hemotoxylin and eosin, × 600).

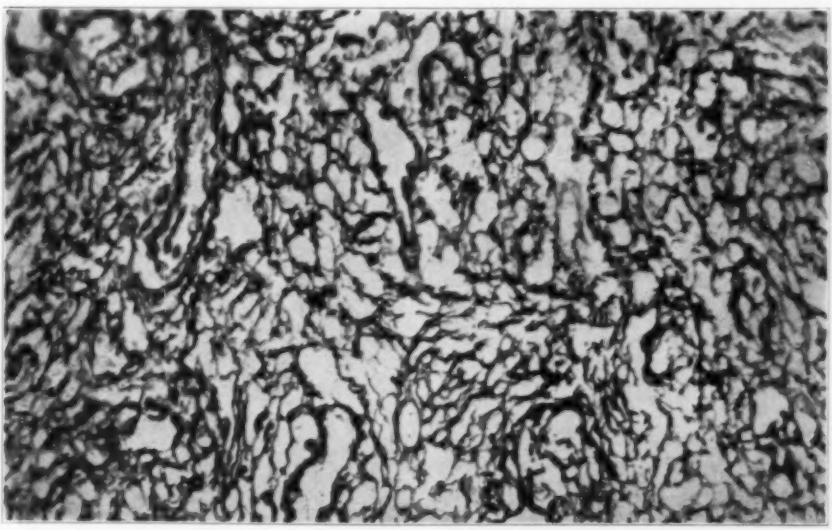

FIG. 4-B

Photomicrograph of hemangiopericytoma with Wilder reticulin stain. This clearly demonstrates the typical reticulin framework of this tumor with the prominent vascular pattern. The tumor cells lie outside the reticulum (× 600).

be separated from it. The popliteal vein was exposed above and below but was lost within the tumor mass; it was sacrificed. Large arteries which appeared to be the superior and inferior geniculate arteries entered the mass. These were ligated. Then, by ligation of vessels at the periphery, we were able to free the mass after sharp dissection from the capsule of the knee at the inferior lateral aspect of the popliteal space. The wound was closed in routine fashion and a pressure dressing was applied. Dicumerol was given for the first five days postoperatively. The posterior tibial and dorsalis pedis pulses remained good and there was very little oedema of the foot. The wound healed *per primam* and the sutures were removed on the ninth postoperative day. The patient left the hospital on the following day. Postoperatively there was partial peroneal palsy; this completely cleared in one year. When the patient was last seen on December 29, 1953, more than five years after operation, he complained of tingling from the knee to his great toe. He was then seventy-four years old, and stated that he "got around as good as ever." There was no evidence of recurrence.

DISCUSSION

Hemangiopericytoma is a rare variant of soft-tissue neoplasms with characteristic cytological detail, cell relationships, and patterning. It occurs in the soft tissues, viscera, and occasionally in bone and has no characteristic clinical features. It is impossible to determine, either grossly or microscopically, the malignant potentiality of a given tumor. It is known, however, that the grade of malignancy is low, but local recurrence and distant metastases can occur. The criteria for recognition were described by Stout. The best means of determining the nature of a soft-tissue neoplasm is through study of a biopsy specimen. When the diagnosis of hemangiopericytoma is made, surgery must be adequate in order that local recurrence and distant metastases may be avoided.

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Unusual Intrameniscal Lunulae

Three Case Reports

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The occurrence of ossicles throughout the body is well documented. An exception, however, is the rare presence of a sesamoid structure within the medial meniscus of the knee. Watson-Jones reported two patients with intra-articular ossicles completely surrounded by normal-appearing meniscus without evidence of trauma or degeneration to explain their development. Pearson studied this subject in man and described ossicles in the meniscus, calling them lunulae.

The clinical importance of intrameniscal lunulae lies in the fact that they would undoubtedly be interpreted as loose bodies, leading to a fruitless exploration of the knee. The author made this error in Case 1, although the true situation was discovered before the procedure had been completed. It is interesting to note that many orthopaedic surgeons who read these case reports and saw the roentgenograms misinterpreted them also. It is obvious that, to recognize these lunulae for what they are, one must be aware of their possible existence.

A review of the literature revealed a variance of opinion as to whether these ossicles are secondary to trauma with heterotopic bone formation or whether they represent vestigial structures. Harris described two cases of rare metaplasia and explained the ossicles as the result of mucoid degeneration. Weaver [6] reviewed the literature and pointed to the existence of primary and secondary types, both calcific and ossific masses, the more common secondary type occurring after trauma and the primary type unexplained. He felt that most cases were secondary with heterotopic bone formation. Pedersen reported gross and microscopic studies of menisci in rodents. He found ossicles frequently present in anterior and posterior horns of the menisci, completely surrounded by cartilage, with-

FIG. 1-A

FIG. 1-B

Roentgenograms of the right knee. Note the location of the ossicle in the posterior horn of the medial meniscus.

out evidence of disease. He concluded that in man, meniscal sesamoid bones may represent a vestigial structure. These ossicles apparently cause mild symptoms of derangement of the knee due to protruding contours which interfere with normal joint function.

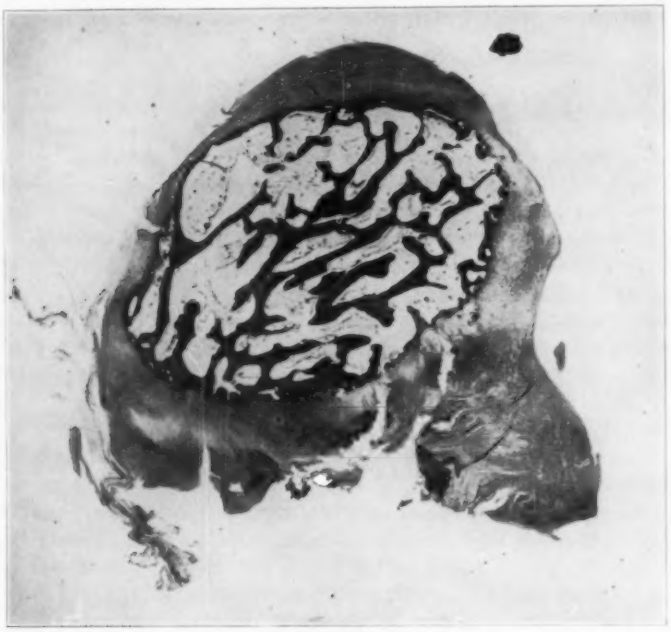

FIG. 1-C

Photomicrograph (× 9) showing nodule of cancellous bone with fatty marrow surrounded by normal fibrocartilage.

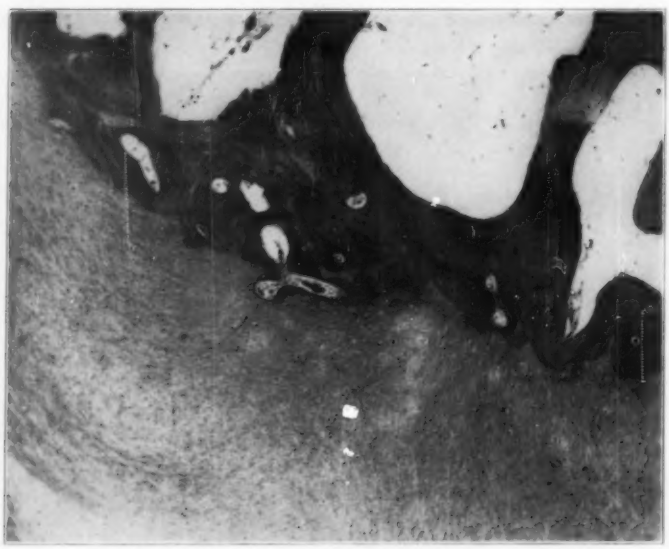

FIG. 1-D

Photomicrograph (× 58) reveals junction of the ossicle to be growing by conversion of surrounding fibrocartilage to bone.

CASE REPORTS

CASE 1. T. G., a white airman, twenty-one years old, noted intermittent pain in the posteromedial portion of the knee and occasional catching sensations for two years previous to his admission to the hospital. During this period, he had had several episodes of minor swelling of the knee. Physical examination revealed no pertinent findings. There was a full range of painless motion, no effusion, and intact collateral and cruciate ligaments. McMurray test was negative. Duck-waddle test caused mild pain in the posterior portion of the knee. Roentgenograms of the knee (Figs. 1-A and 1-B) revealed what was interpreted as a loose body in the joint, possibly of synovial origin because of lack of any demonstrable articular defect. The knee was explored through a small medial parapatellar incision, but neither a loose body nor other pathological condition was found. A posteromedial approach was made and the posterior horn of the medial meniscus palpated with the finger. A hard protuberant mass was felt within the meniscus. The posterior horn was removed and a small bone nodule was seen within the meniscus, surrounded entirely by normal fibrocartilage. A roentgenogram made at the same time showed that the ossicle had been removed. The patient had an uneventful postoperative course and did well on a progressive resistance exercise program. He returned to full military duty without his preoperative symptoms. Sections of the specimens showed a nodule of cancellous bone with fatty

FIG. 2-A

FIG. 2-B

Preoperative roentgenograms of the left knee. Note typical location and appearance. A fabella is also present.

marrow surrounded by normal fibrocartilage. From its appearance, it was felt that the ossicle had formed in the meniscus (Figs. 1-C and 1-D).

CASE 2. R. D., a white airman, twenty-three years old, was first seen because of mild sprain of the medial collateral ligament of the left knee. He also stated that he had noted mild diffuse pain and a catching sensation in the knee for the past six months. No swelling, locking, or instability was reported. Physical examination was negative except for moderate tenderness over the femoral attachment of the medial collateral ligament and pain on passive stretching of this structure. Roentgenograms (Figs. 2-A and 2-B) revealed an ossicle in the posterior compartment of the knee joint. From the experience of the previous case, this was interpreted as a sesamoid bone in the posterior horn of the medial meniscus. Through a Cave incision, the entire meniscus was excised. The cartilage was completely normal except for a bulging bone mass completely surrounded by fibrocartilage within the posterior horn. Postoperative roentgenograms showed that the ossicle had been removed. The patient had an uneventful postoperative course with normal recovery of knee-joint function. When last seen, several months later, he was asymptomatic and had returned to full military duty.

CASE 3. E. D., a white airman, twenty-one years old, was seen in the clinic complaining of an intermittent painful snapping in his right knee of one and one-half years' duration. There had been several questionable episodes of effusion. There was no history of locking or instability. Physical examination was essentially normal except for mild pain in the posterior portion of the knee on duck-waddle test. Roentgenograms revealed an ossicle in the posterior horn of the medial meniscus (Figs. 3-A and 3-B). Through a posteromedial incision, the involved horn of the medial meniscus containing the bone nodule was removed (Figs. 3-C and 3-D). The patient had an uneventful postoperative course, and returned to full military duty one month later without further complaints referable to his knee.

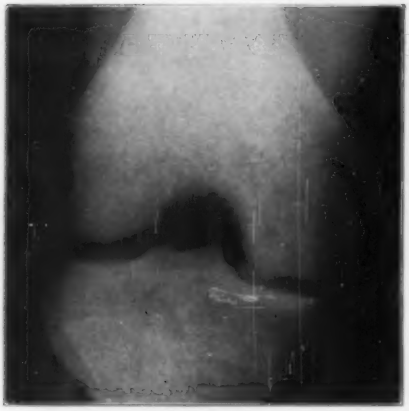

FIG. 3-A

FIG. 3-B

Roentgenograms show meniscal lunule in identical location in medial meniscus. Note the similarity in appearance, especially in lateral view, to the roentgenograms in other cases.

FIG. 3-C

FIG. 3-D

Fig. 3-C: Meniscal lunule, inferior surface, with surrounding normal fibrocartilage.
Fig. 3-D: Meniscal lunule, superior surface. Note the protruding contours which account for mild symptoms of internal derangement.

DISCUSSION

These three patients, when added to the few previously reported cases, tend to add weight to the belief that these ossicles are vestigial structures rather than the products of localized degenerative changes in the meniscus. The otherwise normal meniscus, the sesamoid-like structure, and the striking similarity in location and roentgenographic appearance speak against a metaplastic etiology. A logical explanation for the relatively short duration of symptoms in a sesamoid, which must have been present for many years, lies in the probability that these ossicles are capable of growth and enlargement and do not produce symptoms until their size becomes significant. They must be differentiated from loose bodies to avoid the possibility of a fruitless arthrotomy when a joint mouse is searched for and not found.

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Clinical Manifestations of an Accessory Palmaris Muscle

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Anomalous muscles, while of fundamental concern to the anatomist, have been primarily of academic interest to the surgeon. Rarely do they produce significant clinical symptoms; their importance is that of appropriate identification during surgical dissections. Occasionally, however, an accessory muscle may simulate a tumor or be symptomatic. This occurred in a patient in whom an accessory palmaris muscle produced pressure symptoms which were relieved by surgical excision.

G. T. #00-02-10, a twenty-year-old white man, was admitted to the North Carolina Memorial Hospital in September 1952 because of a mass on the volar aspect of the left wrist. This had been noted during the preceding four to five years and seemed to have increased in size during that time. Symptoms occurred only upon use of the left hand and were characterized by early onset of fatigue in association with a feeling of the hand being "dead." In particular, the patient had noted that, whereas a three-minute typing test was readily performed, a five-minute test was accompanied by fatigue throughout the left hand. Similarly a "dead feeling" was produced by carrying a bucket of water in the left hand and he was unable to hold playing cards in the left hand for prolonged periods without some discomfort. There was no definite pain or paraesthesias corresponding to the distribution of either the ulnar or median nerve.

On physical examination the pertinent findings were confined to the left forearm. On the radial side of the flexor carpi ulnaris tendon a mass appeared upon flexion of the wrist. This mass measured approximately two centimeters in diameter, was hard, non-tender, and seemed fixed. On extension of the wrist, the mass disappeared although on deep palpation there seemed to be some increase in the soft tissue in this area. There was no evidence of atrophy of any of the intrinsic muscles of the hand nor was there evidence of motor weakness or diminution in any of the modalities of sensation. With the preoperative impression of a ganglion, exploration of the wrist was carried out under arm tourniquet and field-block anaesthesia. The tumor was not evident until active flexion and ulnar deviation of the wrist were performed. At this time an anomalous muscle was seen to arise from the palmaris longus tendon on its ulnar aspect (Fig. 1). The origin covered approximately 1.5 centimeters of the palmaris longus tendon and was located four centimeters proximal to the volar carpal ligament. On flexion of the wrist this muscle contracted producing a hard

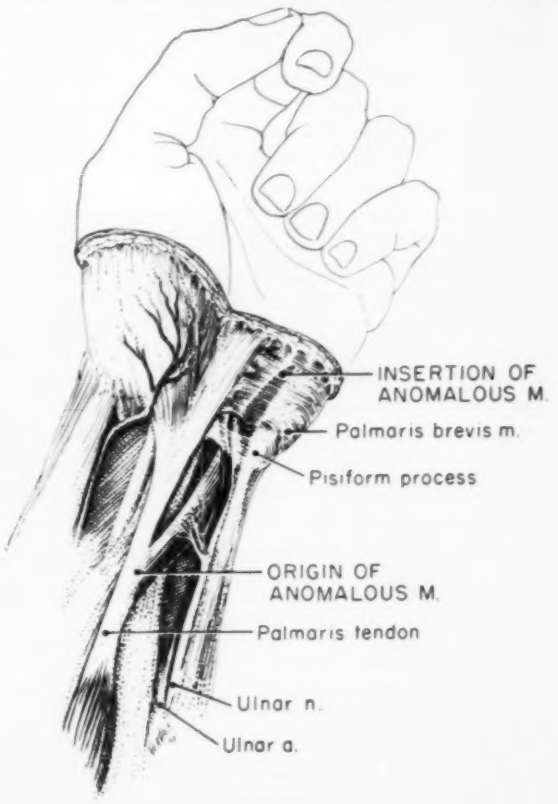

FIG. 1

Sketch of anomalous muscle as seen at time of operation.

mass two centimeters in diameter. Its course was traced distally and noted to pass on the radial aspect of the pisiform with a few fibers inserting there and then beneath the palmaris brevis to the region of the hypothenar muscles. Upon contraction, the bulk of the mass overlay the flexor tendons of the wrist as well as the ulnar nerve. Because of the associated symptoms the anomalous muscle was excised in its entirety. Particular care was taken to note its innervation and a small vessel and nerve were found to arise from the ulnar vessels and ulnar nerve coursing to the muscle about three centimeters above the pisiform. The postoperative course was uneventful, re-evaluation being made at two years and at four years. At these times, the patient was completely asymptomatic with no discomfort or fatigue noted in the distribution of either the median or the ulnar nerve. Strength in the left hand was comparable to that in the right hand with no symptoms following activities that had previously produced discomfort.

DISCUSSION

Compression of the median and ulnar nerves at the wrist has been noted to be associated with symptoms of dysaesthesia, hyperaesthesia, and paresis of the intrinsic muscles of the hand. For the most part these symptoms have been attributed primarily to a tight carpal tunnel and less frequently to a ganglion [1,2,6]. Ulnar-nerve involvement is usually caused by a ganglion arising from the volar aspect of the carpal bones and disturbing the function of the entire nerve or its deep branch. Median-nerve palsy is more likely to be caused by compression of the nerve during its course through the carpal tunnel, although pressure symptoms from ganglia have been reported [1]. In this instance, the clinical symptoms seem best explained on the basis of compression of the nerve and adjacent tendon by the anomalous muscle mass.

In retrospect, the clinical findings should be almost pathognomonic of this condition with the knowledge that in most instances such a structure arises from the palmaris longus tendon and inserts into the ulnar border of the hand. Flexion and ulnar deviation of the wrist should accentuate the appearance of such a mass whereas extension with relaxation of the muscle contributes to its disappearance. Since in most instances innervation is by the ulnar nerve, further confirmation could be procured by anaesthetizing the ulnar nerve at the elbow.

Similar but less conspicuous findings have been recorded from anatomical dissections by Reimann in a survey of anomalies of the palmaris longus muscle. Accessory slips were found in fifteen of 530 limbs, the most common type being an accessory muscle arising from the palmaris tendon and inserting into the abductor digiti quinti. Others reported isolated instances of an accessory palmaris muscle being present [3,4]. In none of these instances, however, did it seem that the muscle was as well developed as it was in the present case nor did it seem likely to produce clinical symptoms. Morrison noted ulnar innervation of these structures, lending support to the view that their origin is from the hypothenar muscle mass rather than from the palmaris longus.

Clinically, such an anomalous muscle has not previously been reported. In most instances clinical recognition is of academic interest only and operative treatment is rarely necessary.

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Modified Nail for Hip Fractures

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Three-flanged or four-flanged nails are generally used for internal fixation of intracapsular and extracapsular fractures of the neck of the femur. The nails in general use, both solid and cannulated, have a blunt tip. From a mechanical point of view, it is apparent that the blunt-tipped nail cannot be driven into the lateral cortex of the femoral shaft before the removal of much of the cortex at the site of introduction. Generally, removal of cortex is accomplished by drilling a hole of which the diameter is slightly smaller than the external dimension of the nail. Another method commonly used to facilitate introduction of the nail is the chiseling out of considerable cortex in a triangular pattern to match the three flanges of the nail; this may contribute to nail extrusion when bone absorption takes place at the fracture site.

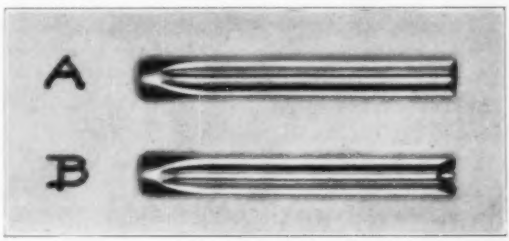

FIG. 1

A, three-flanged nail with blunt tip; *B*, modified three-flanged nail. Note recessed central portion and protruding ends of the flanges.

If sufficient lateral cortex is not removed, introduction of the nail is met with considerable resistance which requires vigorous hammering to accomplish cortical penetration. It is not uncommon to find that the lateral portion of the femoral shaft splits because of the excessive force necessary to drive in the blunt tip of the nail.

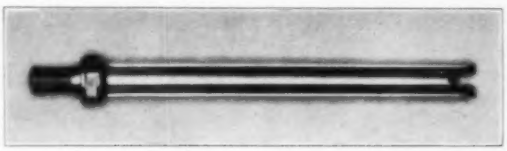

Fig. 2

Modified four-flanged nail. Note osteotome-like ends of flanges.

The nail as modified by the author has for its purpose the elimination of the disadvantages of the blunt-tipped nail, without impairing its efficiency or over-all mechanical strength. The protruding flanges with their osteotome-like ends enable the surgeon to insert the nail with greater ease and safety than he could when using the blunt-tipped nail.

Use of the modified nail makes unnecessary drilling a hole in the lateral cortex of the femoral shaft or chiseling through its full thickness to permit easy penetration at the site of insertion. Elimination of these disadvantages gives the newly designed nail a firmer and more stable grip in the lateral aspect of the femur.

The insertion of this nail requires no special instruments or skill other than that possessed by any surgeon experienced in hip surgery. The technique that the author has used consists in placing the nail at the chosen site on the lateral surface of the femoral shaft. With the driver attached to the nail, a few blows are struck with a hammer, the force of which creates an impression of the flanges on the cortex. With a chisel or osteotome the cortex is penetrated for a depth of about one-sixteenth inch throughout the flange pattern, the width of these cuts in the cortex being one-thirty-second inch for each flange. Then the nail is driven into the neck of the femur in the usual manner. The ease with which the bone is penetrated by virtue of the protruding flanges will minimize

the possibility of rotating the head, especially in subcapital fractures, when driving the nail into place. Likewise, riding up of the nail along the femoral shaft during insertion can be entirely eliminated. Since less vigorous hammering is necessary to introduce this modified nail, the chances of splitting the femoral shaft are greatly minimized.

This newly designed nail is made of Vitallium. In every detail of size, dimension, and resistance to breaking and corrosion, it conforms to the blunt-tipped nail made of the same material. The only variation is in the design of the tip. The central portion of the nail at the tip is ground down with a fine carborundum wheel, so that it is depressed three-sixteenths inch from the distal end, causing the flanges to protrude beyond the central portion. The protruding flanges are tapered by a grinding process, giving them the appearance of a wedge, with the base of the wedge toward the proximal end of the nail. The base of the wedge has the same thickness as the unmodified flanges, that is one-sixteenth inch, tapered to one-thirty-second inch. The distal ends of the protruding flanges are designed to give a moderately sharp leading edge for easy penetration of the bone.

Recent tests performed in the testing laboratory of Austenal, Inc., New York, N. Y., comparing the physical strength of the blunt-tipped nail with the modified nail, revealed the fact that the protruding flanges at the tip did not bend or break under the test load. The test was conducted by placing the nails in a rigid plate adapter at an angle of 135 degrees, the load being applied at the tip so that the testing machine plate was in contact with two flanges.

Results of these tests indicated the yield strength of the blunt-tipped nail to be 174 pounds and for the modified nail 178 pounds, indicating there was no loss in over-all strength of the nail due to modification of the tip. The test further indicated that the protruding flanges did not bend or break under the load applied.

With the increased advantages resulting from the protruding flanges, there has been no sacrifice in strength or holding power of the nail. Since June 1956, my colleagues and I at the Beekman-Downtown Hospital have inserted eighteen nails in transcervical and intertrochanteric fractures of the femur. These patients have been followed for a period ranging from two months to one year. A recent operative procedure is not included in this series. During this period of follow-up, there has been no extrusion, bending, or breaking of the nails.

SUMMARY

The modified hip nail has the following advantages: (1) ease of insertion; (2) minimization of rotation of the femoral head when the nail is being driven in; (3) prevention of riding up of the nail on the femoral shaft; (4) minimization of the chance of splitting the femoral shaft; and (5) removal of less lateral cortex for insertion, allowing a firmer grip of the nail laterally.

A Flexible Meniscotomy Knife

BY VINCENT E. LEGGIADRO, M.D., PORT CHESTER, NEW YORK

The difficulty encountered in excising the meniscus is the mobilization of the posterior quarter which is completely hidden by the fibular collateral ligament of the knee joint on the lateral side and the medial condyle of the femur on the medial aspect.

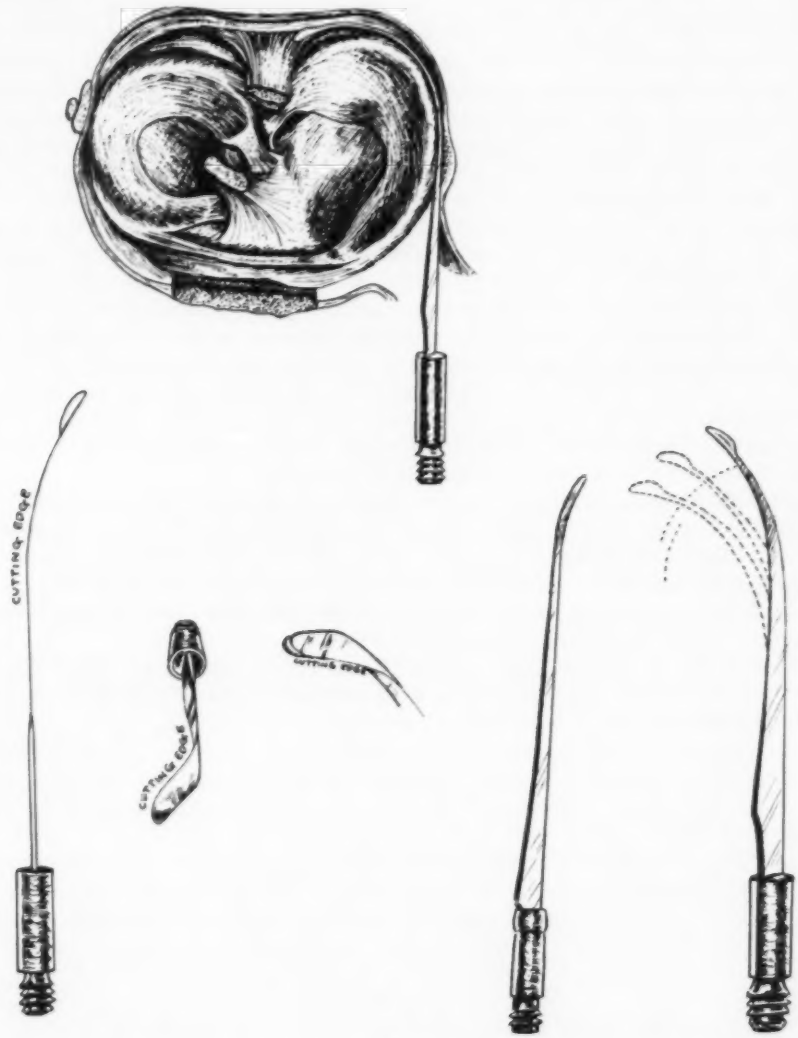

Fig. 1

At the lower right is shown the larger knife used to detach the posterior horn of the meniscus. Its flexibility and gliding action are illustrated. Beside it is shown the No. 2 knife with the rigid smaller curve used to sever the posterior attachment and the anterior horn of the meniscus. At top center is shown a drawing of the lateral and medial menisci, viewed from above, with the knife in place.

In all traumatic injuries of the meniscus, from simple avulsion to bucket-handle derangement, an anteromedial incision provides a good view, except for the posterior horn, which should be routinely removed. The difficulty becomes greater if the posterior horn is firmly attached, and a secondary posteromedial incision is necessary—or the Cave, Anderson, or DePalma incision might be made in advance.

A flexible knife has been developed which has proved efficient in freeing the posterior horn of the meniscus. It is made of stainless spring steel; it is slightly less than one-half millimeter thick and five millimeters wide. It has a semiovoid bulge on the lateral side of its distal extremity, sloped in such a way as not to interfere with its cutting edge.

Through the anteromedial approach, the meniscus is detached up to the tibial collateral ligament. Then the knife is introduced into the posterior compartment of the joint, parallel to the tibial plateau, until it rests on the periphery of the meniscus. Introduction of the knife is facilitated by the presence of the protuberance or bulge on its distal end. With slight pressure on starting a back and forth motion, with a stroke of one-quarter inch or more, the cutting edge will sever the coronary ligaments. As soon as the blade penetrates the meniscus, the stroke may be increased, because the blade cannot deviate from its original path. The operation should be continued without interruption until the blade penetrates to its full depth. Several strokes are necessary to complete the detachment. At this time, the entire meniscus may be displaced easily into the intercondylar notch if the leg is abducted to the thigh. Then with the No. 2 knife, two millimeters wide and with a slightly more rigid curve, the posterior attachment is severed through the intercondylar notch. Thus, the entire excision of the meniscus is accomplished with ease, precision, and in less time. There is no danger of severing either cruciate ligament with the knife, because when the tip of the knife rests on the posterior horn, the posterior cruciate ligament is above its cutting edge; when the posterior attachment is detached the anterior cruciate ligament is also above the knife. The No. 2 knife will also detach the anterior portion of the meniscus up to the tibial collateral ligament.

Although the space is limited, after the insertion of a retractor to safeguard the tibial collateral ligament and for a better view, there is still ample space for the introduction of this thin blade. The posterior compartment of the knee joint forms not a true curve, but almost a right angle. No other knife can follow its configuration precisely.

The flexible meniscotomy knife is also useful in severing the zona orbicularis of the hip joint, when the hip is adducted slightly or externally rotated.

The stainless spring-steel blades are practically unbreakable, even with rough handling. The complete set consists of a handle and four blades, two for the medial and two for the lateral meniscus.

The Changing Picture of Orthopaedic Practice*

BY GEORGE O. EATON, M.D., BALTIMORE, MARYLAND

In the same quarter of a century that has seen such tremendous change in electronics, air transportation, nuclear research, and industrial automation, not to mention the growth of the automobile tail fin, there has occurred a great, if not so dramatic change in the practice of medicine generally and orthopaedic surgery in particular. I have in mind not so much the development of new techniques and therapeutic agents, which certainly has been dramatic enough, but the change in that which is the very essence of medical practice, the relationship between the physician and his patient.

When I entered private practice twenty-five years ago, orthopaedic surgery was a much more comfortable occupation than it is at present. In most of the larger urban centers of which I had some knowledge, there was no hospital shortage. Beds were always available, and the patient even had a choice of accommodations to fit his purse and sense of position. There was no waiting period for general hospital admissions. There were no attempts by doctors to get patients admitted through an emergency room at night because by day the admitting office had no available beds.

In those days, the orthopaedist frequently found that a primary part of his practice was convincing patients that an operation would be safe and beneficial. The era was past when hospitals were considered to be places where one went to die, but there was not as yet general acceptance that a stiff knee, for example, was within the powers of man to correct. The orthopaedic surgeon was not widely known. Exactly how many such specialists there were in this period before the organization of the specialty boards would be difficult to state, but communities of less than 100,000 population rarely had one in local practice.

Many of the orthopaedic surgeons acquired their training by means of a preceptorship arrangement. Nearly all the teachers of orthopaedic surgery in medical schools were part-time instructors busily engaged before and after teaching hours with their own private practices. When it came to combatting infection, there were very few specific remedies, and the main reliance was on multiple transfusions, vaccines, and general supportive measures.

Many of the larger urban centers had their hospitals for crippled children which were in effect orthopaedic hospitals. The cases consisted almost exclusively of tuberculosis of bones and joints, poliomyelitis in the subacute and chronic stages, osteomyelitis, and pyogenic infection of joints. Here, unlike general hospitals, there were waiting lists, so much so that the less acute and not so alarming conditions, such as brain damage, speech defects, hemiplegia, and cerebral palsy were not allotted much hospital space.

Today the situation of twenty-five years ago is reversed. The orthopaedic surgeon finds it necessary to exercise his powers of persuasion not to convince patients, as of old, that an operation is advisable but to convince them that non-surgical measures will suffice. Instead of patients being reluctant to undergo hospitalization, the pendulum has swung to the opposite extreme under the influence of prepayment plans, and the surgeon is confronted with patients expecting hospital care when their complaints and anxieties could just as well be remedied in a doctor's office.

Whereas the field of the orthopaedist was once confined in most cases to treating chronic diseases and derangements of the musculoskeletal system, his specialty now cuts a broad swath through all medical care. During World War II and the Korean conflict, the

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orthopaedic service was usually the largest of the surgical specialties in terms of the number of casualties requiring treatment just as psychiatry was the largest branch of internal medicine. In the more peaceful present, the orthopaedic surgeon is entrusted throughout much of this country with the major responsibility in acute trauma of the spine and extremities. As in wartime, the daily casualty lists continue to show a high percentage of orthopaedic cases as cars clash on the highways, and the legion of blue-collar workers goes about its hazardous pursuits and an ever larger army of the elderly stumbles and falls. With such cases mounting, we may view with concern the efforts on the part of some prominent general surgeons to recapture, as it were, the field of trauma to the extremities.

The orthopaedic surgeons have grown with their field. Since their specialty board was established in 1935, some 2,400 trained practitioners have been certified. While their percentage distribution among medical specialists has not changed significantly since 1935, the number of specialists of all types has shown a sharp increase. The results have been more orthopaedic surgeons more widely distributed, so that where once it was rare to find one in a city of less than 100,000 population, it is accepted that communities of 40,000 and even 25,000 can support their own orthopaedic specialist.

The orthopaedic surgeon also has seen great changes in the tools and techniques of his special calling. He has materials and metals with which to work that were unknown a quarter century ago, and a far broader knowledge of how they may be applied most effectively. He has bone banks at his disposal and all that has been learned about bone-grafting. He has chemical and antibiotic weapons against infection that, together with improved surgical techniques, have all but eliminated osteomyelitis as a fatal disease and sharply altered the prognosis in tuberculosis of bones and joints. Children and young adults are limping less today because of the techniques developed to equalize leg lengths. The once common complaint of sacro-iliac pains, only recently a part of the American middle-aged way of life, has dropped from everyday vocabularies as we have learned to recognize the lesions of the intervertebral disc. The open surgical treatment of certain fractures has improved the outlook in many types of cases and the whole field of reconstruction and rehabilitation has undergone a revolution.

We orthopaedic surgeons are the first to admit the continuing room for improvement. We acknowledge that research has not been pressed as hard and as broadly as it should be. We know that our specialty gets less than its deserved attention in many medical schools. Yet nobody can review, even briefly, the past twenty-five years without a sense of pride in the progress made to date and the groundwork that has been laid for improvements yet to come.

Great strides have been made, not by government dictation, not through the waving of monetary wands by philanthropic groups, not because prepayment plans assured physicians of their financial rewards. Basically the progress has come through the free initiative of medical men pursuing their own life interests, motivated by solicitude for their own patients.

With so many new ways to meet the needs of patients, the orthopaedic surgeon's life should be a more satisfying one than ever before. But, as I indicated earlier, private practice is not the comfortable occupation it once was. Just getting a patient into a hospital these days takes far too much of the physician's time and ingenuity. Hospitals are badly overcrowded in many cities, and no small proportion of the patients who jam clinical facilities and who cause others to wait for beds represents unnecessary admissions.

As great a blessing in many ways as the prepayment insurance programs have been, they have done much to foster the rush of patients to hospitals for treatment and diagnostic studies that are as readily available in doctors' offices. Hospitals, as a result, are hard put to meet their duties to the community in the care of true emergencies. Deserving patients suffer harassing delays and physicians suffer for their patients.

Another result, equally telling, is that hospitals swamped with patients are beset by

ever-mounting costs, which require higher insurance rates to meet them. Yet when Blue Cross and Blue Shield agencies go before their local insurance commissioners to get the added income they must have to meet the added costs, a public howl ensues; enterprising politicians, labor organizations, and others begin a chant for an investigation and for more control over costs which, in the final analysis, means control over the practice of medicine.

Blue Cross and Blue Shield are fine as long as they are medically oriented. But in some states the Blue Shield organization is not controlled by physicians, and the situation is likely to worsen if the protests over costs lead to increased demands that there be more public representation in the large prepayment insurance program.

Twenty-five years ago this was no problem. Less than a million persons had health insurance. Today some 110,000,000 persons are covered for hospital charges, 92,000,000 for physicians' charges for surgery, 55,000,000 for physicians' medical charges in hospitals, and 10,000,000 for physicians' home and office charges. This is private voluntary health protection, and it is essential that it remain private.

Even while we talk of private practice, however, and the benefits that have been derived from it, the practice of medicine becomes increasingly less private. Pressing in from one side are the extensive medical services of the Federal Government. From another side comes the pressure from organized workers for completely prepaid group medical plans. And a third factor in the decline of private practice is the fact that many doctors no longer are working as independent physicians.

To take the last trend first, between 13,000 and 14,000 doctors are now government employed, counting those on military duty. Another 11,000 are employed by hospitals as specialists or administrators, and these salaried doctors are in a statistical group apart from some 23,000 hospital interns and residents. Then there are about 7,000 doctors who work for health plans, industry, other doctors, and miscellaneous employers. Finally, there are the combinations of doctors that in the most extreme form reduce private practice to treating a predetermined group of customers at so much a head.

Any doctor may have his own views on the various aspects of changing medical practices. But the change itself cannot be denied. A quarter of a century ago and right on up to World War II, an overwhelming majority of American doctors had their own independent one-man practices. Patients came to them of their own free choice, and the physicians set their own fees for the services performed, taking into consideration all the intimate details that were once so much a part of the relationship between the doctor and his patient.

Today little more than half our doctors are working by themselves. No special virtues are attached to the one-man practice. No ethical or medical principles are breached when doctors join together to provide easier consultation service, better facilities, and more efficient coverage when one doctor is away. When, however, the group-practice movement extends to the point at which doctors hire their own orthopaedic specialist on a salaried basis, certainly the fee-for-service policy has suffered a setback; and when a group of practitioners contract with a large block of patients on a yearly flat-rate basis, it is quite obvious that the independent physician is confronted with a form of competition unknown only a few years ago.

Similarly, no criticism can be leveled at doctors who become clinical faculty members in medical schools. Our medical schools need experienced teachers. If the teaching schedule is such that faculty members can maintain private practices in their own private offices, they are doing no more than continuing the tradition of the part-time teacher, part-time practitioner. When, however, the salaried faculty members conduct their private practices from their medical-school offices, in some instances using tax-supported facilities for their own gain, and in other instances letting the institution handle the fees, then a situation develops that rightly concerns the truly private physician.

As for the second large factor affecting the private practitioner—the ever-expanding governmental programs in this country—the inroads here already are heavy and constitute

a continuing threat. Take the Veterans Administration and its more than 120,000 hospital beds for one example. The original purpose of its medical-care program was to provide for veterans whose disabilities were the direct result of military service to their country. That was and still is a sound humanitarian purpose and a legitimate obligation of our Government. Back in 1924, however, Congress under Coolidge opened the Veterans Administration hospital doors an extra few inches by authorizing the Veterans Administration to admit indigent veterans with non-service-connected disabilities, when spare beds were available. The exceptions soon become the rule.

Today, the tail wags the dog. The veterans whose ailments are in no way attributable to service to their country represent more than two-thirds of the Veterans Administration case load. Instead of their occupying just the beds not immediately needed by others, the non-service-connected disability patients receive the lion's share of the benefits of a program that, in the last fiscal year, cost more than $700,000,000 for in-patient and out-patient care. If any group suggests that this exploitation of the nation's obligation toward military casualties is wrong, as the Hoover Commission did a few years ago, it is greeted with howls and abuse from veterans' organizations.

The medical care provided by the armed services has undergone a somewhat similar expansion, having been extended, two years ago, to cover the dependents of servicemen whether they live at a military post or in their own civilian communities. Requested by President Eisenhower as an inducement to men considering military careers, the dependent benefits authorized by the Congress have opened military medical facilities to parents and parents-in-law of members or retired members of the armed forces, if they are living in the members' households and are dependent on them for more than half their support. Also included are widows and dependent children of members whose death occurred on active duty or in a retired status, as well as the wives and children of living members, including children over twenty-one if they are attending college or are mentally or physically incapacitated.

Perhaps of even more significance to private medicine, the medicare program, as it is called for short, enables the spouse and children of active-duty military personnel to have civilian hospital care at almost no cost to themselves if they live too far from military facilities or if the facilities are overtaxed or do not offer the necessary treatment. This coverage includes semi-private accommodations in civilian hospitals up to 365 days for each admission, all required medical and surgical care incident to hospitalization, complete maternity care, and all diagnostic tests and procedures incident to hospitalization, the only charge to the patient being $25 or $1.75 a day, whichever is higher, for each period of hospitalization.

Medicare has extended the military medical program to the point where it covers more than 2,500,000 dependents and 3,000,000 men in uniform. To begin to see the size of the Federal medical-care program, this figure for military personnel must be added to the more than 22,500,000 veterans who are potential beneficiaries of the Veterans Administration's services. There must also be added the 300,000 beneficiaries of the Public Health Service, the 370,000 Indians and Alaskan natives receiving Federal hospital care, and the 4,000,000 persons who come under the Federal Bureau of Employes' Compensation Act, which covers at-work injuries only.

This is by no means the extent of Government care. The Public Welfare Assistance Program, which continues to grow larger in good times and bad, includes payments for medical services to the needy. Until the amendments of 1956, unspecified Federal-State funds were paid out; an educated guess has put the federal share at between $90,000,000 and $100,000,000 a year. With the amendments, which set up a new category of Federal-State payments for medical care over and above the old subsistence payment limits, costs are expected to more than double and may go as high as $300,000,000 this year.

The 1956 amendments to the Welfare Program provided for direct medical payments

by welfare agencies to physicians, hospitals, nursing homes, and druggists in behalf of more than 5,000,000 recipients of public assistance. The vendor medical payment provisions were amended again in 1957 to clear up problems created by the 1956 amendments, this time giving states a choice as to how Federal funds for medical payments are applied and also permitting the states to continue to make direct payments to recipients for medical and subsistence expenses.

Whether the doctor sends his bill to the welfare agency or the welfare recipient, he comes up against the same governmental controls over how much will be allowed for house and office visits, how much for an x-ray, and how much for this and that. And if the local welfare people are on their bureaucratic toes, he also finds that prescriptions are checked to make sure that an expensive drug is not ordered when a cheaper medication, considered by them to be of equal therapeutic value, is available.

When the more than 5,000,000 public welfare recipients are added to the veterans, servicemen and their dependents, Federal employees, Indians, Alaskan natives, and patients of the Public Health Service, we find that over 37,000,000 Americans are potential beneficiaries of Federal medical services, or one out of every 4.6 residents of the country.

We can all remember the running fight of the 1940's to defeat national health insurance, popularly known as socialized medicine. Politicians and labor leaders teamed up to push hard for the Wagner-Murray-Dingell bill of 1945 and allied schemes in 1946. President Truman was in the White House and his party controlled Congress; but, after extensive hearings, sufficient opposition manifested itself to keep the bills from coming to a vote.

Another big push was mounted in 1947 and 1948, with Oscar Ewing staging a National Health Assembly to build up support for his health insurance program. The assembly, however, could not be stampeded into endorsing socialized medicine, and, in spite of all the pressure from labor and other lobbyists, compulsory health insurance died once again in a Congressional Committee, this time with a Republican Congress offsetting the influence of a Truman administration.

An aroused medical profession in those years was a strong factor in the defeat of a frontal move toward nationalized medicine. Lest we forget, though, that was a decade ago. The doctors may have relaxed since then; their opponents have not. The health insurance program that could not be obtained in one fell swoop has been pushed on a piecemeal basis. Congress enacted bills in 1950, 1952, and 1954 that paved the way for what was a major breakthrough in 1956, the passage by a one-vote margin of the Social Security amendment that authorizes cash disability benefits for workers at the age of fifty if they become permanently and totally disabled, physically or mentally.

As doctors, we know how difficult it is to say with finality that a person is permanently and totally disabled. We know the effect on possible rehabilitation and re-employment that can be produced by labeling a patient as hopeless and assuring him of a monthly income whether he works or not. We also can recognize that payment for physical and mental ailments is a radical departure from the original intent of the Social Security Act to provide old-age and survivors' insurance. But the efforts of organized medicine and others could not turn the tide in 1956. President Eisenhower signed the measure, and it went into effect last July.

The disability payments at the age of fifty are only a first step. Half a dozen bills in the current Eighty-Fifth Congress would permit the payment of disability benefits at any age. Other proposed legislation would liberalize the coverage requirements and redefine *disability*. Still others would provide disability payments to widows at the age of fifty and to blind persons of all ages.

A particularly potent scheme now pending is the Forand bill to furnish hospital, nursing-home, and surgical care for the millions of Americans now receiving old-age and survivors' insurance benefits. Compulsory insurance is back again, sponsored by Messrs.

Murray and Dingell, son of the original Dingell. There are also moves to provide Federal aid to medical schools and health insurance for Federal civilian workers. And, among the encouraging proposals, Representative Roosevelt of California has an amendment to the Longshoremen's and Harbor Workers' Compensation Act that would permit injured workers to select their own physician and hospital.

So great is the Congressional interest in the health field that 250 pieces of health legislation were introduced in the Eighty-Second Congress, 407 in the Eighty-Third, 571 in the Eighty-Fourth, and the present outlook is for at least 640 in the current Congress. Not all of this interest is sinister, of course. Yet often the good intentions of Congressmen knowingly or unknowingly pave a road to regimentation for the private practitioner, as in the case of the Forand bill which provides, among other things, that physicians be paid in such amounts as prescribed in regulations promulgated not by physicians but by the Secretary of Health, Education, and Welfare.

The third large factor in the diminution of private medical practice, along with Government expansion and the shift of doctors to salaried positions, is the drive among organized labor unions to procure full and prepaid coverage of all medical expenses for their members. The threats from Washington in the 1940's have been superseded now by the threats of men with large union treasuries who are not satisfied with Blue Shield plans and with the private physicians who guide those plans. The big labor leaders increasingly want their own medical programs and their own stables of doctors, financed through business contributions to their health and welfare funds.

An article in *Medical Economics* last fall ticked off some of the major labor moves: Walter Reuther and his auto workers, one of the largest of all unions, are pushing ahead with plans for closed-panel medical centers throughout Detroit to provide members with a full range of medical services by doctors on a salaried or per capita basis.

The United Steelworkers, a union that brought over 1,000,000 members into Blue Shield, threatens to withdraw its membership *en masse* when the current contract expires, unless Blue Shield is prepared to offer full benefits regardless of income and comprehensive coverage that includes "early diagnostic and preventive medical care, treatment of the chronically ill, hospital visits, home and office calls, dental, drug, and appliance bills."

The United Mine Workers, whose fiscal report for the year ending June 30, 1957, shows $59,584,594 expended to provide hospitalization in forty-five states, the District of Columbia, and Alaska for 93,679 beneficiaries, was one union that at the outset honored the fee-for-service principle and the right of members to choose any qualified physician. Last year, however, five state medical societies registered complaints with the American Medical Association that the union has begun to put physicians on a salary or retainer basis and limit the members' choice of physicians.

Instead of licensed physicians being accepted as qualified to perform such services as they and their professional peers believe them competent to perform, and instead of hospitals being judged on their individual performances, the miners' health organization frequently of late has assumed the prerogatives of judging treatment given by physicians, the qualifications of physicians for hospital appointments, the selection of hospitals, and the choice of hospital staffs. And as the miners go, so more than likely will go other unions.

Doctors in the mining regions of Pennsylvania have seen clearly enough what happens as a third party comes between physician and patient. The free-choice principle is dropped down an abandoned mine shaft as more and more doctors become dependent on union patronage and drift into union control. One young surgeon put it bluntly when he said, "It's up to us who aren't completely dependent on union payments to carry this fight through to its conclusion. One side or the other has to win."

Colorado doctors have also seen the handwriting on the hiring-hall walls. The medical society there has ruled that any physician who knowingly and willingly participates in a medical plan which denies its beneficiaries the right of free choice of physician shall upon

conviction thereof by appropriate medical tribunal be found guilty of unethical and unprofessional conduct. But if the price is high enough, even this threat of professional condemnation may not be sufficient to stop some doctors from crossing over to controlled medicine.

Nobody in our profession needs a crystal ball to foresee what is in store for private medical practice in this country. When the monolithic AFL-CIO organization announces the formation of a war chest to help defeat medical opposition to labor health plans, and when its president patronizingly remarks that "we only want to help attract the best doctors and bring out the best in them," the prospects of continued union intervention between physician and patient are perfectly clear.

While Blue Shield is the immediate object of labor's attack, it is only the first target in the unions' line of fire, representing the medical profession once removed. This is quite evident when an official of the United Auto Workers levels his verbal gun at Blue Shield for trying, as he says, to "superimpose the concept of prepayment on an archaic system of solo practice." It is made doubly plain when a spokesman for the steelworkers says that Blue Shield has deteriorated into what he calls "a collection agency for the medical profession."

The ancient foe of private medicine, Michael M. Davis, whose promotion of compulsory health insurance goes back to the 1920's, has brought forth the prediction that within ten years only 10 per cent of all payments to physicians will be in the form of fees for service. That may sound fantastic to some of us and, considering its source, a prediction to be classed as the pipe dream of a propagandist. However, Mr. Davis' prophecy does not sound so far-fetched when men from the ranks of medicine, such as Dr. Russel Lee, make similar forecasts.

Dr. Lee, who heads an eighty-physician clinic in California, has served as an American Medical Association delegate and was a member of President Truman's Commission on Health Needs. Interviewed for *Medical Economics*, Dr. Lee said he felt certain that within twenty-five years almost all the medicine in the country will be practiced in prepayment groups. Comprehensive care on a prepaid basis is presumed to be what the patients want, and men like Dr. Lee are convinced that is what they are going to get. "If organized medicine does not accept the idea, there will be plenty of maverick MD's who will."

We had better fall into line, the closed panelists say, or that other goblin—socialized medicine—will get us for sure. A glance into the future offers no assurance whatsoever that doctors by giving up their principles of fee-for-service and free choice of physicians can thereby keep Government medicine from their office doors. On the contrary, it may be that the doctors who sell short the tried and proved principles of the private practice of medicine only serve to weaken what was once a united front and thereby make the whole profession more vulnerable.

How far the nationalization of medicine will go, I myself would not care to predict. The pressure in Washington is there, that's for certain. Social Security provides a ready tax on the earnings of nearly all working Americans. If it can be twisted into disability payments at the age of fifty, as has already happened, or converted into hospital insurance for the aged, as the Forand bill proposes, then there is no guessing what new forms of socialized medicine can be pulled in under the Social Security blanket. The one obvious thing is that new schemes will be proposed and pushed with relentless determination.

Aside from the prospects of compulsory health insurance coming piecemeal under the guise of Social Security, governmental care of the medically indigent, military dependents, federal employees, and millions of veterans surely will continue and will be expanded wherever and whenever the empire builders and pressure groups see an unguarded opening. Political parties rise and fall on Capitol Hill, but the drive toward socialized medicine goes steadily forward, no matter who occupies the White House or the seat of the Majority Floor Leader.

I, for one, do not minimize for a moment what the opponents of a free and independent medical profession are predicting. I believe that the battle lines are drawn and that, in the next few years, the principles of fee for service and free choice of physicians will have had their conclusive test and either will have been successfully defended by an aroused profession and their patients or will have been swallowed up once and for all time.

The only real question remaining is whether private practitioners will rise to the challenge or simply let their profession, including themselves, be overtaken by groups openly aiming to take medicine out of medical hands. The American Medical Association, as we all know, is alert to the dangers and actively opposes each threat that arises. But what do we mean when we say the American Medical Association? Too often we mean a small band of medical representatives in Washington fighting our battles with only nominal support and a cash contribution from us.

The medical profession is not going to defend itself for long with a small task force instead of a professional army fully equipped with facts, rebuttals, and unity of purpose. The doctor who sits in his office and does not know what the Forand bill proposes to do to the concept of Social Security is a doctor who is not likely to wake up until it is too late to fire a shot. The specialist who feels that the hiring of internists or orthopaedic surgeons by the United Mine Workers is some other doctor's worry is a specialist who does not recognize the noose until it begins to tighten around his own neck.

I said at the outset that the practice of medicine twenty-five years ago was more comfortable than at present. Looking ahead, it appears certain that the practice we have today is likely to be more comfortable than that in the years immediately ahead.

Medicine is highly personal, and if we consistently render good personal care, the public will not turn to the anonymous care furnished by clinics with their long waiting periods and changing personal physicians.

No man seriously devoted to medicine can anticipate with pleasure having to play an active role in winning friends and influencing legislation on behalf of private medicine. No man with a full patient load relishes attendance at meetings which are occupied with discussions not of medicine but of bills pending in Congress. Yet we must either throw our full weight in person behind the organizations trying to defend the private practice of medicine or be held accountable for the defeat of a medical system second to none in public service and technical advances.

If we win, medical practice for those who open private offices twenty-five years hence may once again be a comfortable profession which allows a doctor to give full and undivided attention to the one main concern of his life, the care of his patient.

NOTE: The author wishes to acknowledge the interest and assistance of the American Medical Association Washington Office in the preparation of this address, particularly in making available the factual material.

JOHN R. NORCROSS, M.D.
1906-1958

The death of John Norcross on February 16, 1958, at the age of fifty-one years, was a great loss not only to his family and friends, but also to orthopaedic surgery. He had suffered a coronary occlusion seven months previously, but, after an excellent recovery, had returned to the care of his practice, when a second attack took his life within moments while at home. He had accomplished a great deal in his life, but was too young and had too much to contribute to be taken so prematurely.

Jack is universally remembered for his generous friendship and ready wit. His greeting was always sincere and cordial, accompanied by a laugh and a little good-natured banter. He invariably took time to be interested in the other person's problems. He was a man of integrity, kind, sensitive, and unassuming, and these characteristics were of great comfort to his contemporaries as well as to his patients. He served his patients conscientiously and well and was an agile, resourceful surgeon, instinctively adept with his instruments and satisfied with nothing less than perfection. He gave generously of his time in teaching his residents at St. Luke's Hospital, Chicago, where he was Senior Attending Orthopaedic Surgeon, as well as instructing the students of Northwestern University Medical School, where he was Associate Professor of Orthopaedic Surgery.

He will be gratefully remembered for his abundant service to the Academy. In 1947, he first accepted the responsibility as General Chairman of the Academy meeting in Chicago. He possessed a natural talent for organization, attention to detail, and tactful management—these he used with such notable success that he was asked to continue in the office in 1948 and 1949. The considerable accomplishments of those

Chicago meetings were in large measure due to his efficiency. He is entitled to an ample share of the credit for the founding and expansion of the Central Office of the Academy of which he was the first Director, holding that position from 1948 to 1952. From 1952 to 1957, he served with distinction as Secretary of the Academy. Thus, at the time of his death, he was without an Academy office for the first time in ten years, but his intimate knowledge of Academy affairs was of inestimable aid to those following in his footsteps.

His first contribution to the literature was an article on arachnodactylia, published in *The Journal of Bone and Joint Surgery* in 1938; the last, a paper on internal derangement of the knee joint published in 1957 in *Surgical Clinics of North America*. In the intervening years, he wrote articles on a variety of topics, including lesions of the wrist, compression of the spinal cord, and sympathicoblastoma. Of interest was an article on a new type of shelf operation for congenital dislocation of the hip in which portions of bone-bank tibia were cut in right-angle sections and fitted together so as to form a buttressed cup over the femoral head. This was published as a preliminary report in the *Quarterly Bulletin of the Northwestern University Medical School* and had not been completed at the time of his death. With Robert Potter, he demonstrated cases of spondylolisthesis without an isthmus defect in a scientific exhibit at the American Academy meeting in 1953 and these findings were subsequently published in *Radiology*.

Jack's prime interest and love was his family with whom he lived in a beautiful home on the margin of the country club in suburban Glenview. His life with them was ideal and his wife Louise, son John, and daughter Mary Jane shared all of his interests. His recreations were golf in the summer and curling in the winter. He was proficient at both and a session with him on the golf course was a memorable occasion of fun and investigation of this fine art. Typical of the man was his amused pride in the unusual accomplishments of his Labrador retriever, Bard. As no game birds were available on the adjoining golf course, Jack found she had learned to retrieve lost golf balls. This performance was an evening routine as he rested on his terrace before dinner. When she returned wagging her tail with satisfaction after a foray, John would laughingly pick as many as four balls from her mouth, gleefully inspect each for condition and generously offer any or all to his guests.

John Norcross was born in Highland Park, Illinois, May 28, 1906. He received his undergraduate training at the University of Wisconsin and graduated from Northwestern University Medical School in 1931. After an internship and residency at St. Luke's Hospital in Chicago, he continued his orthopaedic training at the New York Orthopaedic Hospital from 1933 to 1935. He was associated with Dr. Fremont Chandler from 1936 until 1938 when he had pulmonary tuberculosis. From 1939 to the time of his death, he was in practice in Chicago at 122 South Michigan Avenue. He served as President of the Chicago Orthopaedic Society in 1948; he was a member of The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, the Clinical Orthopaedic Society, and the International Society of Orthopaedic Surgery and Traumatology.

John was a Christian whose everyday life was colored deeply by his religious convictions. His was not merely lip service, but a matter of day in and day out practice with religious exactness. His short, but full, life is exemplified by the words from The Book of Wisdom, Chapter IV, Verse 13: "Consummatum in brevi, explevit tempora multa."

L. S.

RICHMOND STEPHENS, M.D.
1890-1958

In the passing of Dr. Richmond Stephens on March 17, 1958, the medical profession has lost one of its outstanding practitioners of orthopaedic surgery, and the Hospital for Special Surgery of New York City has lost not only its oldest professional staff member, measured in years of service, but also one of its best loved personalities.

"Rich" joined the staff of the old Hospital for the Ruptured and Crippled, which many years later became the Hospital for Special Surgery, as a student intern in 1911. He served on its staff continuously up to the time of his death, with the exception of a few years immediately after his graduation from the College of Physicians and Surgeons, Columbia University, in 1913. During this interval he was surgical intern on Dr. Eugene Poole's service at New York Hospital, he served overseas in World War I with Base Hospital No. 9, which was the New York Hospital Unit, and he married the present Ella Stephens, who was a nurse at New York Hospital and who also served with the unit overseas. They have two sons.

Upon his return from France, he rejoined the staff of the Hospital for the Ruptured and Crippled as Clinical Assistant, and during the years climbed to the rank of Attending Surgeon, which position he filled with distinction for many years before his death. Further evidence of his professional attainments were his membership in the American College of Surgeons (Fellow), in The American Academy of Orthopaedic Surgeons, The American Orthopaedic Association, and in the exclusive and distinguished Robert Jones Club. His inclusion in this last organization marks him not only as a man of attainment in orthopaedic surgery but also as one having such personal charm that other distinguished orthopaedists sought his friendship.

Dr. Stephens' warm and friendly temperament, combined with his long association with the Hospital

for Special Surgery, resulted in his knowing practically every member of the personnel. And, since knowing him meant liking him, his friends and admirers, with the comings and goings over the years, were myriad. Hosts of the residents and other personnel of the hospital will remember with happiness the genial and gracious hospitality of Dr. and Mrs. Stephens on summer Sundays at their home in Newtown, Connecticut, where he added the profession of New England dirt farmer to that of orthopaedic surgeon. They will remember the lovely farmhouse, the pool which he had created by damming a brook in the valley just behind the house, and the extensive and picturesque young orchard which he personally had set out on the hill beyond. Those of a kindred spirit will also recall looking over the large stamp collection he enjoyed so much.

Dr. Stephens' rare and courageous spirit was especially manifest shortly before his going. Some of his friends who visited him then will long be impressed by the keen interest he took in their personal affairs, with nothing more than a casual reference to his own downhill course, this containing no trace of complaint, bitterness, self-pity, or fear.

Truly, as a doctor and as a friend he will long be remembered.

R. W. L.

GENE DELMAR CALDWELL, M.D.
1906-1958

On March 10, 1958, at the age of fifty-one years, Dr. Gene Delmar Caldwell died. He was born in Wymore, Nebraska, on March 21, 1906, he matriculated at the University of Omaha, and he subsequently received his medical degree at the University of Nebraska on January 31, 1930. Following a two-year internship at the Grasslands Hospital, New York, he served a two-year residency in surgery at the Cleveland Clinic from 1932 to 1934. Because of the stimulating influence of Dr. James Dickson, Dr. Caldwell's interests turned to orthopaedics. Following a one-year residency at the Shriners' Hospital for Crippled Children in Shreveport, Louisiana, he served as a resident at the New York Orthopaedic Dispensary and Hospital for two years. Upon completing his training in October 1938 he returned to Shreveport, Louisiana, and entered into practice in association with Dr. Durham, an orthopaedic surgeon. He was called into service with the rank of First Lieutenant soon after the outbreak of World War II and served with distinction in the 2nd Auxiliary Surgical Unit in the Mediterranean Theater. His surgical skill was readily recognized, resulting in his rapid promotion to the rank of Lieutenant Colonel.

Upon his discharge from the service in 1945, he returned to Shreveport where he resumed his practice and his association with Dr. Durham.

In a very short time he was appointed director of the Shriners' Hospital for Crippled Children, Chief Consultant of the Veterans Administration Hospital, and Clinical Professor of Orthopaedic Surgery at the Louisiana State University Post-Graduate School of Medicine. He was a Founder Member and Past-President of the Russell A. Hibbs Society, Past-President of the New York Orthopaedic Alumni Association, diplomate of the American Board of Orthopaedic Surgeons, a member of The American Academy of Orthopaedic Surgeons, the American College of Surgeons, the American Association of Bone and Joint Surgeons, the Clinical Orthopaedic Society, the International College of Surgeons, as well as many other state and local medical organizations.

Gene Caldwell was a surgeon's surgeon. He had technical skill and sound judgment. His contributions in the field of orthopaedic surgery were not many, but each was sound and each earned him respect and admiration.

His affectionate gentleness and his soft, soothing, Southern drawl as he examined an apprehensive youngster at the Shriners' Hospital were a symphony of human understanding and compassion. Yet, he was vehemently intolerant of any pretense. His was such a complete and absolute honesty in every endeavor that it stamped him a man apart. His motives were never questioned. He gave all too freely of himself to his friends who, so often, sought his advice. Gene was a good thinker, and he championed the cause he thought right. Seldom was he wrong, for he had a keen analytical mind.

Dr. Caldwell is survived by his wife, Nancy, a sixteen-year-old son, Gene McFadin, and a ten-year-old daughter, Nancy Eileen.

He will live in the memories of those of us who treasured his close friendship.

N. J. G.

Proceedings

AMERICAN SOCIETY FOR SURGERY OF THE HAND

The Thirteenth Annual Meeting of the American Society for Surgery of the Hand was held January 31 and February 1, 1958, in New York City, under the Presidency of Dr. J. Edward Flynn of Boston, Massachusetts.

On January 30, 1958, the Society met for a one-day clinical session in Boston, Massachusetts, the clinical program having been organized by Dr. Flynn.

Dr. Bradford Cannon [1] and Dr. Joseph Murray [2] presented an interesting series of cases on the care of burned hands. Many of the patients were present for inspection by the audience. They stressed the principles of care. Particularly important was early coverage, including the use of open grafts. The technique of opening the webs secondary to the burns was demonstrated. Surgical debridement was said to be better than any of the chemical agents. The latter have been tried and discarded. Most of the cases presented were long-term, severe burns of the hand. Dr. William Metcalf [3] discussed the presentation and told of his experience in treating burned hands only by elevation and with no dressing. He was gratified by the manner in which the slough separated, leaving surprisingly good skin underneath in many instances. It was pointed out that this avoided the necessity of anaesthesia for dressings. Dr. Darrel Shaw [4] felt that pressure dressings were valuable for a few days and that then the wound could be left open.

Dr. William F. Flynn [5] presented a case in which the thumb had been almost completely amputated, having only a small volar skin flap. Reconstruction of the thumb was accomplished by bone graft and pedicle flap. The iliac-bone graft was just long enough to allow the thumb to press against the base of the index finger when it was completely flexed at the metacarpophalangeal joint. Flexor and extensor tendons were inserted into the bone graft and function was good. Dr. Flynn also presented a second case illustrating unusual motor recovery after complete median and ulnar nerve transection.

Dr. William E. Browne [6] presented his experience with flexor-tendon grafts. Most of these had been done in patients with difficult conditions. Almost all of them had had previous surgery which, to some extent, compromised the results. The palmaris longus tendon was preferred for the graft. Motion-picture films were used to present the cases. Despite the difficulty of the problem, the end results were quite gratifying. In many, several operations were necessary.

Dr. Edward Hamlin [7] and Dr. Robert Shaw [8] discussed the vascular problems involving the upper extremity. They pointed out that they are no longer doing sympathectomies for Raynaud's disease. However, in those patients who showed cold intolerance without a true Raynaud's picture, they had had good results from sympathectomy. It was their feeling that patients with arterial emboli to the major vessels of the upper extremity should have embolectomies. They preferred autogenous-vein grafts for arterial replacement. They pointed out that by creating an obliquity at the suture line one may actually make the suturing of the very small vessel easier.

Dr. Henry C. Marble [9] and Dr. Gordon Meyer presented in detail the interesting case history of a woman with severe causalgia of the right hand and arm. The patient later had coronary thrombosis with severe pain in her left arm. Xylocaine block of the right arm relieved the causalgia and the angina on the left. The results of numerous blocks were presented. Dr. Gordon Grant [10] suggested that blocks are more successful if hyaluronidase is used with the blocking agent.

Dr. J. Edward Flynn [11] presented a number of cases of thenar palsy. In the treatment of thenar palsy, various methods of tendon transfer were used. These included the techniques of Thompson, Bunnell, and others. There was an excellent discussion of Dr. Flynn's presentation by Dr. J. William Littler [12] and Dr. Daniel C. Riordan [13]. Dr. Littler emphasized that when all of the thenar muscles are paralyzed and one has only a single transfer, it may be advisable for this transfer to be inserted into the short thumb flexor

1. 275 Charles Street, Boston, Massachusetts.
2. 319 Longwood Avenue, Boston, Massachusetts.
3. 1085 Park Avenue, New York, N. Y.
4. 10525 Carnegie Avenue, Cleveland 6, Ohio.
5. 475 Commonwealth Avenue, Boston 15, Massachusetts.
6. 587 Beacon Street, Boston, Massachusetts.
7. 275 Charles Street, Boston, Massachusetts.
8. Massachusetts General Hospital, Boston, Massachusetts.
9. 270 Commonwealth Avenue, Boston, Massachusetts.
10. 47 Bay State Road, Boston, Massachusetts.
11. 350 Medical Arts Building, Victoria, British Columbia, Canada.
12. 14 East 90th Street, New York 28, N. Y.
13. 1538 Louisiana Avenue, New Orleans 15, Louisiana.

without removing it from the carpal tunnel in order to provide good strength for apposition and adduction of the thumb. Dr. Riordan emphasized the need in those patients who have weak long extensor tendons and a long-standing palsy of extending the transfer which is used for opposition over and inserting it into the long extensor tendon, in order that the patient may have more strength in extension of the terminal phalanx.

Dr. J. Englebert Dunphy [14] presented an interesting discussion of the repair of tissue after injury, demonstrated by means of slides. There was an interesting demonstration of the way in which healing occurs. Of particular interest was the migration of the prickle-cell layer into the depths of an incision.

Dr. Francis D. Moore [15] presented an excellent discussion of the present concepts of blood volume, blood loss, and blood replacement, particularly emphasizing the fact that there is less blood in the body than we think. He stressed the fact that the normal blood volume can be calculated on the basis of the kilograms of body weight times a factor of approximately 7 in the male and approximately 6.4 in the female. He pointed out that one sees very few signs with only 10 per cent loss of blood volume, while a 25 per cent loss of blood volume gives early signs of tachycardia, fainting, and a gradual rise in the diastolic blood pressure. The loss of blood volume must reach 30 to 50 per cent before actual hypotension is seen. The hematocrit is an excellent index of pure blood plasma loss, but is not of much value in the single acute hemorrhage, the average patient taking twenty-four hours to show a response in the hematocrit due to acute hemorrhage. The hormone influence to the smooth muscle in the small vessels was pointed out to include a relationship between the 17-hydroxy-ketosteroids, the epinephrine-like hormones, and the sodium and potassium balance. It was emphasized that the sodium citrate present in the blood used for transfusion may have one of two effects in the body, depending upon whether it is oxidized or non-oxidized.

Neuropathic Trophic Disorders of the Hand. Dr. Derek E. Denny-Brown [16] discussed the clinical syndromes presented by peripheral-nerve damage in syringomyelia, tabes dorsalis, leprosy, diabetic neuropathy, and familial sensory neuropathy. He differentiated between the painful and the painless peripheral-nerve syndromes, pointing out how the vasoconstrictor effect of cold may become sidetracked and produce a pain response. He emphasized that the neural equilibrium of some patients is precarious and that some individuals may thus develop an obsessional type of pain.

Dr. Edward MacMahon [17] presented an excellent discussion on Baron Guillaume Dupuytren—the man, the surgeon, and the disease that bears his name. Included was a discussion of the etiology of the disease, as well as a discussion of the gross and microscopic findings.

Dr. C. Gardner Child, III [18], made a very interesting presentation on the role of a hand surgical service in a university surgical department. He described such a program and many interesting aspects of the surgical service were presented.

New York City, Friday, January 31

Newer Concepts of Wound Healing. Dr. J. Englebert Dunphy [14] presented a change in the concept of tissue repair on the basis of chemical and histochemical studies. There is a difference in the healing in epithelial tissues, granulation tissue, and special tissues. The progess of healing in a surgical incision was demonstrated in slides. The migration of the prickle-cell layer into the depths of an incision was clearly shown. This occurs before the appearance of granulation tissue. Evidence seemed to be against a hormone factor in wound healing. Protein starvation as a factor in wound healing was discussed. It was pointed out that ordinarily wounds in a young animal will heal better than wounds in an old one. However, in the presence of protein starvation, wounds in the older animal will heal better than those in a younger one. The importance of ascorbic acid as a factor in collagen formation was stressed. Sick people need an increase in ascorbic acid. Scurvy presents a specific block to collagen formation. It was pointed out that contraction of wounds is not cicatrization. It is not simply an aging of collagen tissue. Wound contraction results from a migration of tissue. Skin-grafting ordinarily stops this contraction or, if the graft is particularly thin, it will only slow the contraction. In circumstances in which contraction is desirable, skin-grafting is not indicated.

Severe Compression Injuries of the Hand in Industry. Dr. Michael L. Lewin [19] reviewed his experience with twenty-five cases of compression injuries of the hand and forearm. The injuries were due to industrial accidents involving hot rollers and presses. Severe tissue damage resulted, with loss of cutaneous structures, tendons, nerves, muscles, and exposure of bones and joints. Of the injuries, 80 per cent involved the dorsal surface of the hand and forearm.

In selected patients in whom adequate débridement could be performed initially and in whom the

14. 818 Harrison Avenue, Boston, Massachusetts.
15. Peter Bent Brigham Hospital, Boston, Massachusetts.
16. 818 Harrison Avenue, Boston, Massachusetts.
17. 136 Harrison Avenue, Boston, Massachusetts.
18. 818 Harrison Avenue, Boston, Massachusetts.
19. 67 East 78th Street, New York 21, N. Y.

wound was free of necrotic material and infected pockets, primary definitive resurfacing with a flap was carried out. However, in most of the patients repeated débridement was required. In these patients the primary aim was to cover the wound with a temporary skin graft. Before this was accomplished the exposed joints had to be obliterated and the denuded bone decorticated in order to obtain a granulation surface.

Almost all of the injuries required a flap for definitive resurfacing. This was essential in order to obtain a protective subcutaneous pad, to revascularize the damaged bone, and to permit a subsequent surgical approach to the deep structures. The flap covered the fingers mitten fashion. In subsequent operations, the fingers were separated. Throughout the entire treatment the hand was splinted in a functional position. When a stable tegumental cover was provided, efforts were made to mobilize the preserved joints by dynamic splinting, capsulectomies, and exercises. Occasionally functional alignment was improved by osteotomy or arthrodesis.

The adduction contracture of the thumb was corrected by excision of the scar or fibrosed adductors, or both, and by replacement with a full-thickness skin graft. As a final step, kinetic replacements were performed by tendon grafts or tendon transfers. A pinching and grasping mechanism was restored in all patients, which, together with normal sensation, made for a useful hand.

Volar injuries had poorer prognosis as regards rehabilitation because of the damage to the neurovascular supply and because they could result in a frozen, anaesthetic hand. In a patient with an extensive volar injury amputation was eventually done. Dissection of the specimen showed complete fibrosis of the nerves which was attributed to the strangulating effect of the scarring.

Dr. Hans May [20] suggested that it was helpful in such cases in preventing abduction contractures to use two types of flaps. He said that he uses a dorsal flap to cover the surface of the hand and a pocket flap to close the dorsum of the fingers.

Dr. John L. Bell [21] suggested that in hands severely damaged and in which there was concomitant burning the excision of devitalized tissue might have to be performed in several stages. He also suggested that devitalized bone be removed by means of a small chisel rather than drilling the cortex of exposed bone to prepare this for skin coverage.

Dr. Raymond Curtis [22] recommended the use of a primary pedicle flap as a means of maintaining and achieving future function.

Dr. J. Edward Flynn [11] asked Dr. Lewin how he would treat extensive avulsion wounds over the volar and dorsal aspects of the hand when skin, subcutaneous fat, and fascia have been completely avulsed.

Dr. Lewin said that in such a case he would place the hand in a pocket so that the palm lies against the skin flap. He would then resurface the dorsum of the hand with split-skin grafts at a later date.

Primary Reparative and Reconstructive Procedures in the Severely Injured Hand. Dr. Robert M. McCormack [23] and Dr. Jerome W. Craft emphasized the need for the surgeon who treats the hand at the time of the primary injury to be able to carry out all of the specialized reparative surgery indicated at the time of primary treatment whether that represents skin replacement, bone alignment, nerve repair, or tendon repair. This concept was illustrated by excellent case presentations of (1) the crush avulsion type of injury from severe blunt trauma, (2) gunshot wound treated under civilian hospital conditions, and (3) multiple tissue injury such as from farm accidents. It is the feeling of the authors that the only absolute indication for primary amputation in a hand is loss of blood supply to the part.

Sound surgical judgment, they pointed out, requires a knowledge of both the benefits and the limitations of reconstructive procedures for all the tissues of the hand, not merely those of a given tissue specialty that are best known to the surgeon.

Dr. Bradford Cannon [1] emphasized the value of the free skin graft for wound closure and pointed out the risks of the removal of bone in a wound which is secondarily infected because infection may spread to the marrow cavity and beyond. When bone, tendons, and even joint cavities are exposed because primary closure with a flap could not be carried out, they are usually surrounded by granulation tissue. The likelihood of spreading infection or further destruction of these tissues can be greatly decreased by reducing the total area of the open wound with free skin grafts. The grafts can be applied up to the exposed bone, tendon or joint, none of which will nourish the grafted skin. With the surrounding wound closed, these structures will no longer be bathed in pus, their condition will improve, and many times spontaneous healing over what appeared to be non-viable bone, tendon, or open joint will occur. The type of definitive repair with a flap will have been postponed but can then be done under ideal circumstances.

Dr. Elden C. Weckesser [24] said that there was one problem which troubled him in his enthusiasm for primary coverage, that is the coverage for gunshot wound. He recently had a patient who received a gunshot wound of the arm at close range. Within twenty-four hours of injury, he had debrided and grafted

20. 255 South 17th Street, Philadelphia 3, Pennsylvania.
21. 154 East Erie Street, Chicago 11, Illinois.
22. 2919 St. Paul Street, Baltimore 18, Maryland.
23. 260 Crittenden Boulevard, Rochester 20, New York.
24. 10465 Carnegie Avenue, Cleveland 6, Ohio.

the wound, only to lose the graft. He found that the blast had devitalized the soft tissue much deeper than he had appreciated in his original débridement.

Dr. J. Edward Flynn [11]. What are the indications for delayed closure of wounds?

When would you use wire fixation for open fractures?

When would you attempt primary reconstruction of injured tendons?

Should one then perform a primary or late reconstruction of injured nerves?

Should antibiotics be used as a prophylaxis in the treatment of open wounds in a hand; if so, what antibiotic would you suggest?

Dr. McCormack in closing said that regardless of the severity of the wound seen in the first few hours, under present-day civilian hospital conditions, good operating-room conditions, good anaesthesia, good immunization, a delayed closure as far as the hand is concerned is only of historical interest. He feels that it is much more difficult to gain good results with old granulating wounds as compared with primary closure and that the major emphasis should be put on initial primary closure and extremely meticulous repair.

As to wound coverage and healing, he thought that there is not much question, when final functional results are compared, whether one can possibly obtain primary closure regardless of dirt contamination, oil or grease. It is preferable to delayed closure.

He does not use Kirschner wires across a joint unless absolutely necessary. He always bent and buried Kirschner wires and did not leave them sticking out through the skin.

For a crushed tendon he would not attempt primary repair and said he considers such an area as needing débridement of all tissues, including muscle and crushed tendon.

It was emphasized that primary nerve repair is more complicated. In the purely sensory nerves of the hands, he feels that sensory return is good, and he aims for a primary wound repair, including nerve sutures, on the night of the injury. In some cases it might have been better had secondary repair been done in view of the collagen present.

He said he uses antibiotics for severe multiple injuries, usually penicillin and streptomycin. He emphasized that there is serious controversy on this point particularly at present with the high hospital incidence of resistant strains.

The Psychological Impact of Serious Hand Injury. Dr. Gordon H. Grant [10] discussed the emotional and psychological aspects of major hand injury.

An overwhelming majority of surgical patients apparently emerge from even serious and prolonged ordeals without detectable instability or measurable lowering of intelligence. Many patients, however, bring unstable personalities to their surgical ordeals. Patients who suffer injury, especially recurrent injury, are apt to be pathologically careless, tense, hostile, or apathetic. These patients are candidates for serious psychological trouble, especially when the period of treatment must be prolonged and the eventual disability severe.

A variety of factors influences the patient's psychological progress after serious hand damage; the most important probably is his relationship with his surgeon. If the patient, rightly or wrongly, comes to regard his surgeon as casual, as lacking in interest or sympathy, his fears deepen and resentment is added to his distress. This resentment is rarely overtly expressed; it may be expressed through lethargy, anorexia, or a spurious stoicism. Explanation of what has gone wrong and what is going to be done should be reinforced by visual demonstration with an atlas of anatomy.

A few patients seize on disability as a respectable excuse for retiring from the battle of life. These and other victims of non-amputative injury might benefit from highly organized help such as is now extended to the amputee.

Three patients became psychotic after serious hand disability. Their histories and psychological reactions were discussed.

Dr. Condict W. Cutler, Jr. [25], pointed out, in discussion, the intimate correlation that exists between the hand and the brain in man. He feels that because of this association hand injuries might be more shocking than would otherwise be the case. The importance of a clear understanding of the problem by the patient was stressed. It is his practice to demonstrate the nature of the condition to the patient by the use of roentgenograms, illustrations, and even pencil sketches. He feels that this is of great value in calming the patient's apprehension.

Reconstruction of Congenital Abnormalities of the Upper Extremities. Dr. Martin A. Entin [26] based his report on 120 patients with abnormalities of the upper extremity who were divided into two main groups: (1) those with some anomaly of the upper extremity only and (2) those with some general systemic disturbance in addition. In order to crystallize the reconstructive need, the first group of sixty-one patients was classified on the basis of clinical and anatomical manifestations.

25. 260 Park Avenue, New York, N. Y.
26. 1538 Sherbrooke Street West, Montreal, Quebec, Canada.

The primary aim of reconstruction was to provide the basic need of the limb, namely, good skin and sensation, the ability to place the hand in strategically useful position, and satisfactory pinch and grasp in the hand. These basic needs were provided with the least number of surgical procedures and required stabilization and bone support, phalangization of fused digits by shifting local and distant skin, transfer of digits to provide pinch and grasp, and muscle transfer to give motion to newly constructed parts.

The discussion of the specific procedures used was presented for a few selected cases, thus illustrating the individual needs and stressing the complexities of reconstructive procedures. Deformities of the radial component comprised the largest group of the anomalies of the forearm. These varied in severity, the most severe requiring stabilization of the hand by fibular graft and pollicization of the index finger for absence of the thumb to provide prehension. Reconstruction of missing digits comprised the more difficult problems and entailed transfer of skin pedicles and of bone struts or of the entire toes; both methods have their limitations and neither method restored normal function to the deformed hand. Reconstructive procedures, such as phalangization and local and distant skin transfer were required for fused, webbed, and partially amputated digits.

In the second group there were fifty-nine patients in whom the deformity of the upper extremity was due to a systemic disturbance or was associated with it. Some of the deformities were similar in configuration to the anomalies of the first group of patients and required similar management.

Because of the dynamic changes inherent in the process of growth, deformity may recur even after successful reconstruction. Constant vigilance is required to correct these.

Dr. Arthur J. Barsky [27] said that for thumb replacement or substitution, he believes that the migration of a digit on a neurovascular pedicle is preferable to the pollicization procedure, which involves the use of an abdominal pedicle and requires several stages. The use of a neurovascular pedicle is a good deal simpler and has the advantage of being a one-stage procedure which yields results that are functionally and aesthetically satisfactory.

Both in thumb hypoplasia and in the so-called floating thumb, the level of the metacarpophalangeal joint of the thumb is much too distal, generally, at the level of the metacarpophalangeal joints of the other fingers. In the floating thumb, with its deficient or absent metacarpal, he is now first moving the digit on a neurovascular pedicle to the region of the thenar eminence and then, at a second stage, doing a free transplant, from the toe, of a metatarsophalangeal joint. The proximal end of the tarsal bone is mortised into the adjacent metacarpal and a lap joint created on the opposite end. Subsequently, tendon transfers into the finger are carried out. It is much too early to state that complete growth and development will take place, but at the present time he felt encouraged to continue along these lines.

In cases of ectrodactylia, when the fingers are clumped and many of the distal phalanges are missing, if spherical nubbins of tissue are present, he tries to transplant these nubbins to the tips of the fingers when the digits are separated in order to give added length. Just how much sensation the tips will finally have he could not at this time say for his patients are all too young to give reliable responses.

In syndactyly, he advised locating the digital nerve immediately after the palmar incision has been made and tracing its course. Sometimes he found that instead of two normal branches, one major trunk will run along the border of one finger and bifurcate much more distally than one would expect. The nerve should then be split back so as to provide innervation for the adjacent side of the other finger. This same approach should be used in ablating a polydactylous digit, especially when it is on the thumb side.

Radial club-hand is an extremely difficult condition to treat. He said that the forearm is shortened and that, no matter what one does, it will still be short. Furthermore, early operation will prevent bowing of the ulna, but the operative procedure might possibly interfere with growth and development. Although bowing might be corrected, the hand cannot be used.

Transplantation of the upper end of the fibula as a strut certainly seems to hold some promise.

Dr. Daniel C. Riordan [13] said that the habit pattern which children with abnormalities of the upper extremity develop is perhaps responsible for our poor results. One may, for instance, do a beautiful reconstruction of such an abnormality as absence of a thumb; yet the patient will not use the thumb in the new position. He thought in patients with congenital amputations when there is no hand on either side but there is an arm that is long enough for biceps transplantation, the transplantation will give some form of sensation which cannot be obtained by any other means.

Procurement, Processing, Storage, and Clinical Use of Homografts. Cmdr. George W. Hyatt [28] described the Tissue Bank Department of the National Naval Medical Center. It is primarily a clinical research and development unit, emphasizing a study of the human homogenous graft. While it was stressed that the autogenous graft is the ideal transplant, the information and observations obtained from evaluating homogenous grafts provide the basis for the observation that there is a place for the homogenous graft, either fresh or stored, in orthopaedic surgery. The homogenous grafts were procured from over 200 sterile

27. 174 East 72nd Street, New York 21, N. Y.
28. National Naval Medical Center, Bethesda, Maryland.

postmortem tissue excisions. Over 5,000 individual tissue deposits were processed, and such deposits were used in the surgical treatment of over 2,000 patients.

The biology of the homogenous graft was discussed with particular reference to its antigenicity, viability, and capacity for assimilative induction.

The recently deceased provide the source for all homogenous grafts. Donors must be free of all infectious diseases and malignant conditions. All tissues are removed under aseptic conditions. The methods of processing the freeze-dried homogenous graft and the quality control of production were discussed.

A continuing effort is made by the medical records division to present data on the clinical success or failure of homogenous grafts.

Clinical data for follow-up in twenty-six of forty-three extensively burned patients treated with homogenous-skin grafts, as well as sixty-four patients with fresh fractures treated with homogenous-bone grafts were presented. In the latter group, there were four graft failures.

DR. WALTER C. GRAHAM [29] stated that he had personally not had a great deal of experience with this type of work but that he had used frozen tendons in an experimental project on rabbits. He felt that these would work entirely satisfactorily.

Some Problems in Flexor-Tendon Repair. DR. ERLE E. PEACOCK, JR. [30], reported the results of a group of experiments designed to reveal the best method for investigating and controlling tendon adhesions. The experiments were arranged in logical sequence to provide a foundation for the following clinical conclusions:

1. Tendons are provided with a definite blood supply to support a measurable metabolic activity.

2. Blood vessels entering from either end of long tendons are not adequate to nourish the central third. The center of long tendons is nourished by intermediate segemental blood vessels.

3. The center of free tendon grafts is nourished by vessels which form in postoperative adhesions. To prevent adhesions successfully with a mechanical barrier will produce necrosis in the center of the graft.

4. In vascular pedicle tendon transfers in which a segment of the intermediate blood supply is protected, adhesive complications are less likely to develop than with free grafts.

5. Composite tissue heteroplastic grafts of the flexor mechanism from human cadavera can be successfully transplanted beneath the abdominal wall of animals. Grafts which have been stored until they no longer respire in the Warburg apparatus cannot be transplanted successfully and are rapidly replaced by cicatrix.

6. The secretion of synovial fluid and preservation of the gliding mechanism is regarded as evidence for survival. A single example of a fuctioning human homogenous graft of the flexor mechanism was presented.

DR. WALTER METCALF [2] said that the healing of autogenous-tendon grafts at the proximal and distal ends, and their contiguous thirds, suggests that re-establishment of the capillary network occurs by growth into the graft from the remaining proximal and distal normally vascularized tendon (in which continuity is being re-established by the graft). This emphasizes the importance of not freeing the proximal and distal ends to too great a distance, thus risking the loss of this axial circulatory component. The additional importance of the circulation accruing to the central section of the graft from the surrounding soft tissue across the paratenon has been stressed by Dr. Peacock. The need to dissect all scar and thus allow contact between normal soft tissue and the graft becomes apparent.

The use of homologous tendons as grafts has not gained popularity. The normally occurring abundant supply of expendable tendons elsewhere in the body has obviated this use. However, the possible use of homogenous-tendon grafts, either immediate or stored, raises the question of their healing. The fact that they are not rejected outright suggests the immediate analogy with the current widespread successful use of large homogenous-blood-vessel grafts. It is accepted that the latter do not take *per primam* in their native form but are slowly and gradually replaced by fibrous tissue in the recipient. It would be most interesting to study homogenous-tendon grafts to see if they, too, undergo such replacement and redifferentiation.

The ingenious, and to my knowledge, original use of the tendon, synovial sheath, and fibrous sheath composite as a homogenous graft is a most interesting and important contribution. However, it must be emphasized that this is an early observation in a single case and that no other conclusions be drawn from this work than those Dr. Peacock has himself noted in this paper.

Injuries to Flexor Tendons and Nerves of the Hand in Children. DR. JOHN L. BELL [31], DR. MICHAEL L. MASON [31], DR. SUMNER L. KOCH [32], and DR. WILLIAM B. STROMBERG [32] presented their experience with sixty children who sustained tendon or combined tendon and nerve injuries of the flexor surface of the hand. Sixty-four operative procedures were performed in these patients. Repair of divided flexor structures was undertaken in five, and in fifty-six patients secondary reconstructive procedures were performed. The

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30. University of North Carolina, Chapel Hill, North Carolina.
31. 154 East Erie Street, Chicago 11, Illinois.
32. 154 East Erie Street, Chicago 11, Illinois.
33. 154 East Erie Street, Chicago 11, Illinois.

majority of the patients were less than six years of age. Operative techniques in children were the same followed for older patients. The preoperative diagnosis of tendon injuries in the child too young to cooperate was not difficult provided careful observations of the posture of the hand were interpreted properly. In the young child, nerve injuries could be suspected by the location of the surface wound. However, the absolute identity of nerve interruption had to be confirmed at the time of the operative procedure.

The secondary procedures included tendon grafts within the flexor sheaths of the fingers and thumb and repairs of multiple nerve and tendon injuries in the palm. Thirty-four children had tendon grafts inserted into the fingers; of these children, 65 per cent were less than six years of age. Seven patients had tendon grafts of the thumb and fifteen had secondary repairs for injuries in the palm. Although the structures are smaller in the child's hands, the operative procedure was often less difficult than that in the adult hand. In the majority of the children, the interphalangeal joints were supple, and scarring was less than that occurring in older patients. In most of the children the long extensor tendon of a toe was used for grafting.

The maintenance of postoperative immobilization of the hand is frequently a challenge in the child under six years. In the child too young to cooperate suture removal was carried out under general anaesthesia. Formal physical therapy was not prescribed for children.

Follow-up examinations were continued at yearly intervals in many of the young children before the end result could be ascertained. Fifty-three children were included in the follow-up study. In children of different ages, the variance in hand size precluded the use of measurements other than degrees of active and passive motion. The influence of the preoperative condition of the hand upon the result following tendon reconstruction should be stressed. Excellent results following tendon repair in children were determined according to criteria set for older patients. However, lesser stages of functional return were assessed with more difficulty. In fifty-three patients, twenty-three excellent and eighteen good results were obtained after either primary or secondary tendon and nerve reconstruction on the flexor surface of the hand.

Dr. Joseph H. Boyes [34] commented on the relatively small number of primary repairs which had been done. He stated that this indicated a careful selection of cases made for primary repair. He pointed out the importance of having the tissue of the hand in good condition at the time of secondary repair and stated that this is in direct relationship to what is done to the finger before. The least that is done at the time of the accident in attempting to repair the tendons, the less scarring there will be and the less of a problem there will be with secondary reconstruction. Dr. Boyes prefers the palmaris longus to the toe extensors for a graft. He also recommended the use of catgut sutures for the closure of the skin in a child. He feels this avoids the necessity of removing the skin sutures under general anaesthesia.

Delayed Advancement in the Repair of Lacerated Flexor Profundus Tendons. Dr. Carruth J. Wagner [35] pointed out that when the flexor profundus tendon is lacerated distal to the insertion of the sublimis, several methods of repair are available. These include primary and delayed suture in continuity, tenodesis or arthrodesis of the distal interphalangeal joint, primary or secondary tendon-grafting, and primary or delayed advancement of the lacerated tendon.

Advancement appears more nearly to restore the normal function of the lacerated flexor profundus tendon and is accompanied by a minimum of complications. Delaying the advancement allows the wound to heal, fractures to stabilize, and traumatized joints to recover. Restoration of tendon continuity can then be accomplished under elective rather than emergency conditions.

Advancement of the profundus to the distal phalanx places the suture line at its most advantageous location and overcomes the complications of mid-finger adhesions and fixation seen with sutures in continuity.

Dr. Darrel T. Shaw [36] said in discussion that his experience had been similar to Dr. Wagner's. Most of his patients had had skin closure or attempted repair by the referring surgeon. In his experience it had proved difficult preoperatively to determine the amount of scar and tissue reaction accurately. Advancement was not used if there was extensive scar or reaction proximal to the divided proximal end. The proximal end of the divided profundus tendon may be found in the finger at the level of the sublimis denervation. If the sublimis had been partially divided the detached end was sutured away from the gliding area of the profundus.

He had also used profundus-tendon advancement in selected cases of primary repair and had successfully advanced the sublimis insertion to the profundus insertion on the distal phalanx. After firm union he used a dynamic extension splint postoperatively if necessary.

Primary Tendon Repairs. A Study of 789 Consecutive Tendon Severances. Dr. Alex P. Kelly, Jr. [34], analyzed a consecutive group of 556 patients with 789 severed tendons by the use of punch-cards. An effort was made to find differences in the excellent, good, and poor results at the various levels of injury which

34. 1401 South Hope Street, Los Angeles 15, California.
35. United States Public Health Service Hospital, San Francisco, California.
36. 2799 West Grand Boulevard, Detroit, Michigan.

might be helpful in indicating proper treatment. The results were judged by criteria similar to those of Kyle and Eyre-Brook for flexor tendons and of Miller for extensor tendons.

In the extensor injuries there were satisfactory results in 90 per cent. Analysis of the various levels of injury revealed, however, that injuries in the proximal and distal portions of the finger had a high proportion of poor results. The injury of the proximal portion of the finger associated with fracture was especially troublesome, and a plea was made that this injury be handled only by those thoroughly familiar with the anatomical and physiological problems of this area.

In the flexor injuries satisfactory results were obtained in 80 per cent of the cases.

In repairs in the critical sheath area there were satisfactory results in 70 per cent. In the group with poor results there were significantly higher numbers of complicating factors, such as crushing injuries, nerve injuries, fractures, dubious vascularity, and skin loss, than there were in the group with excellent and good results. There was an unexplained high incidence of poor results in the female patients in whom immediate and delayed repair was done. The conclusions reached after study of this group are that repairs in the sheath level are still governed by the magnitude of the trauma and that the therapeutic advances of the past decade have not altered the basic concepts set forth by Koch, Mason, and Allen. The surgeon must be prepared to judge accurately which tendons should be repaired and capable of carrying out the repair flawlessly.

The major complications in this study resulted from antibiotic therapy, anaesthesia, and the psychological impact of the injury, suggesting that all three areas of therapy be weighed carefully by the surgeons when dealing with the local injury.

Dr. Joseph L. Posch [37] stated that during a similar five-year period of time 770 patients with injured tendons were seen at the City of Detroit Receiving Hospital. This was presented only to indicate the very large number of tendon injuries that are encountered in a large metropolitan area. Dr. Posch felt that Dr. Kelly's criteria for evaluating his results were unnecessarily critical. He felt that many of the patients who had been classified as having poor results actually had a useful functioning hand.

Saturday, February 1

Circulation of the Hand. Injection Corrosion Studies. Dr. J. E. Markee [38] and Dr. J. B. Wray [39] presented a detailed study of the circulation of the soft tissues of the hand. The major arteries of two freshly amputated hands were injected with Batson's plastic within fifteen minutes of severance in the operating room. After the plastic hardened, the specimens were treated with a concentrated potassium hydroxide solution to remove all organic matter. This resulted in a remarkably detailed cast of the vascular tree that was painstakingly dissected and photographed.

Certain observations were deemed worthy of reporting and include:

The dermis of the skin is densely vascularized and contains a large quantity of the circulation of the hand. In general, the density of the vascular bed seems related to the amount of pressure usually applied to the part. The volar aspects of the palm and fingers are most dense.

While the subcutaneous areas do not exhibit outstanding vascular beds, the palmar fascia and the tendoretinacular structures are richly vascularized.

The vascular beds of the hand are fed by arteries which approach at right angles to them. This is well demonstrated in the finger tip where many branches proceed at right angles to the anastomotic connection of the two common digital arteries. On the other hand, the veins draining these beds usually run parallel to them and lie in the subcutaneous spaces.

Although the results of this study are not conclusive, the authors feel that the technique can be applied to more definite studies including a quantitative evaluation of the circulation of the hand.

Dr. Emanuel B. Kaplan [40] feels that a great deal more needs to be learned about the blood supply of the ligaments of the wrist and fingers and that it is only through such studies that the needed information can be obtained.

Dr. Herbert Conway [41] mentioned a study which had been done by him and Dr. R. B. Stark (*The Journal of Bone and Joint Surgery*, **36-A**: 1238–1240, Dec. 1954) based on the arterial injection of ten specimens from cadavera. They used thorium dioxide. It was their finding that the palmar tissues consistently showed a triangular zone of limited arterial vascularity, the apex of the triangle being proximal. This triangular zone was surrounded by three zones of marked arteriolar vascularity, the thenar area, the hypothenar area, and the palmar area distal to the flexion crease. Dr. Conway believes this observation to be of practical importance in the management of avulsion flaps and in the surgical treatment of Dupuytren's contracture.

Migration of a Radial Digit on a Neurovascular Pedicle. A One-Stage Procedure. Dr. Arthur J. Barsky [27] presented a case of an eight-year-old boy in whom each hand had five digits composed of three

37. 1405 Kales Building, 76 West Adams, Detroit 26, Michigan.
38. Duke University School of Medicine, Durham, North Carolina.
39. Duke University School of Medicine, Durham, North Carolina.
40. 1001 Grand Concourse, Bronx 52, New York.
41. The New York Hospital, 525 East 68th Street, New York 21, N. Y.

phalanges, none of which was opposable. The radial ray on each hand was shortened and rotated in a one-stage procedure into a position permitting opposition and pinch. The end result in these two hands was excellent and a motion picture demonstrated the range of motion which had been achieved.

A Case of Thumb Substitution with the Third Finger after Lucksch-Hilgenfeldt. DR. HANS MAY [20] believes that the most effective thumb replacement is by the substitution of another finger. During World War II, Hilgenfeldt of Germany revised and improved the original Lucksch procedure in which the finger to be used as a thumb is transferred by means of a skin, vessel, and nerve pedicle. Whenever possible he used the middle finger for substitution. Bunnell and Littler went one step further and transferred the finger to be substituted on the neurovascular bundle alone without the skin bridge. Hence, the vascular-pedicle "island" flap (Monks and Esser) provided the principle for the neurovascular-flap transposition of a digit.

Littler originally used the index finger for substitution and developed a versatile and reliable method. The procedure, however, requires more dissection than Hilgenfeldt's. Hilgenfeldt, as already stated, prefers the middle finger over the index finger for substitution. He argues that the index finger has greater range of abduction and adduction; it has greater usefulness and for this reason should be left *in situ*. That the ring finger and even the little finger can be transferred even without the skin bridge, that is, attached only on the neurovascular bundle, has been recently demonstrated (Kelleher and Sullivan).

Hence, any finger can now be used for substitution of the thumb. The most important requirement is that the circulation of the finger to be used is adequate. If it is impaired or doubtful another finger must be used for substitution. According to Hilgenfeldt's procedure, which was employed in the author's case, the dorsal skin, vessels, nerves, and extensor tendons are severed, the metacarpophalangeal joint is disarticulated, and a volar-skin bridge not more than one centimeter wide containing flexor tendons, volar digital arteries, and nerves is formed. The finger is transferred upon the stump of the first metacarpal bone and the extensor tendon of the transferred finger is anastomosed to the long extensor tendon of the thumb, and the volar-bridge flap is permanently incorporated. In the same or second stage the long flexor tendon of the thumb is transferred to the flexor profundus tendon of the middle finger.

DR. J. WILLIAM LITTLER [12] said in discussion that in substituting for the thumb when all four fingers are present the use of the middle finger is wrong. He feels that the thumb is an important member of the hand, and the next digit to it should be used as a substitute. The index finger is, of course, adjacent to the site of loss. It may be somewhat damaged and the vascular supply may be such as to prevent its further transfer. If, however, the vessel on the ulnar side is still present, together with its sensation, when shifted into working position the sensation is then on the working side of the digit. He feels it is advisable to have a flap between the thumb and the opposing finger because it gives better motion.

DR. JOSEPH H. BOYES [24] demonstrated with slides the case of a patient who had lost most of his thumb and also had damaged the little finger. There was an ununited fracture of the fifth metacarpal. This little finger was rotated beneath the median nerve on its neurovascular pedicle with the flexor tendons intact. A small skin graft was used to complete the closure and a satisfactory result was obtained.

Surgery of Tophaceous Gout. A Case Report. DR. HAROLD W. WOUGHTER [42] said that reports of surgical reconstruction of hands affected by tophaceous gout are extremely rare in the literature. Linton and Talbott reported eleven cases in which surgical removal of tophi afforded relief of pain. Significant was their remark that at the Massachusetts General Hospital from 1835 to 1935 only seven patients with gout were treated surgically—three for evacuation of tophi and four for amputation.

In this case Dr. Woughter took surgical advantage of the peculiarities of tophaceous gout. He was able to transfer an unaffected phalanx of the useless index finger, with its blood supply intact, to the middle finger. This filled a gap left by the removal of a disabling tophus. During the five and a half years that this patient was observed, the gout showed a predilection for the smaller bones and joints of the hands and feet. Encroachment upon the larger joints was mild. When tophi were incompletely excised there was no tendency to recur. A tophus, which in itself was the architectural framework for support and not seriously interfering with function, was not disturbed. Surgical wounds healed promptly and well.

DR. ROBERT E. CARROLL [43] said that we tend to forget that gout involves the hands as well as the feet. The deposition of urates in the hand usually is a slow process and the neurovascular bundle is not damaged. This fact allows rather extensive surgery with a reasonably good prognosis. Surgical scars do heal nicely and apparently prevent return of urate deposits in that area. It is felt that there are two major indications for surgical intervention. The first indication is to prevent mechanical disability. When the deposits cause joint instability and digital angulation, they should be removed at an early date. If a deposit on a finger grows in size so that it is difficult to put on a glove, it should be removed. The second major indication for surgical care is involvement of the skin covering the tophus. We should not wait until the skin becomes necrotic and a draining sinus forms.

42. 1312 Mott Foundation Building, Flint, Michigan.
43. 180 Fort Washington Avenue, New York 32, N. Y.

Is Brachial-Plexus Block the Ideal Anaesthesia for Hand Surgery? Dr. John W. Ditzler [44] and Dr. Robert H. Clifford [45] evaluated 526 brachial-plexus blocks administered to private patients for hand surgery by doctors of varying skill in the administration of anaesthesia. The study indicated 5 per cent block failures and 85 per cent to have been wholly satisfactory to the surgeon. Seventy-five per cent were perfect technical blocks as judged by stringent criteria. None of the partially successful blocks required more than intravenous meperidine or a small amount of local infiltration. The authors feel that this method of anaesthesia, although safe and reasonably efficient in their hands, is not a substitute for local anaesthesia where applicable but is appropriate when the other logical choice is general anaesthesia.

Especially important is the decreased physiological trespass upon patients who (a) are taking various medications such as hormonal or ganglioplegic drugs and (b) have intercurrent disease states. Brachial-plexus anaesthesia is important for the patient with recent food ingestion, as is the case for emergency operative procedures where introduction of general anaesthesia is not without serious hazard.

Stated objections to brachial-plexus anaesthesia have been delay in induction time, patient displeasure, and complexity of performing a block. These were not serious problems.

Thirty-three of the patients (13 per cent) had some postoperative complaint which initially was alleged to have been due to the anaesthesia. There was an incidence of pneumothorax of less than 1 per cent. Several sequelae were felt to be "compensationitis" and bizarre paraesthesias from arm slings and the like. Regardless of etiology, in a few patients, serious and prolonged problems of postoperative management developed, in part attributable to the brachial-plexus block.

Dr. Louis Orkin [46] stressed the importance of training in the use of brachial-plexus blocks. He feels for elective hand surgery general anaesthesia is ideal, but agrees that in certain acute injuries and in cases complicated by other diseases the brachial-plexus block is desirable. In his experience, pneumothorax has also been the most frequent complication.

The Carpal-Tunnel Syndrome. An Anatomical and Clinical Study. Dr. Radford C. Tanzer [47], in a review of seventeen cases of carpal-tunnel syndrome which included a detailed anatomical study of seven operative cases and a comparable study of the tunnel in seven unselected cadevera, made the following observations and conclusions:

1. Compression of the median nerve in carpal-tunnel syndrome occurs in the proximal third of the tunnel, the point of abrupt transition from the thinner to the thicker portion of the transverse carpal ligament being the level at which compression is usually most pronounced.

2. Manometric studies of pressures within the carpal tunnel, done with distensible rubber bags, demonstrated that the proximal half of the tunnel undergoes significant pressure increases on both flexion and extension of the wrist whereas the distal half shows increase on extension only.

3. Clinical and anatomical observations lead to the conclusion that the most significant motion in the production of the carpal-tunnel syndrome is repeated, combined, forceful flexion of the wrist and fingers, based on the concept that this motion squeezes the median nerve in the carpal tunnel between the taut flexor tendons and the unyielding anterior wall and proximal rim of the carpal tunnel.

4. The presence of a family history of median-nerve compression at the wrist in three of our cases suggests that a predisposing factor may be inherited. Furthermore the finding of six anatomical abnormalities in the region of the carpal tunnel in sixteen surgical explorations suggests that the predisposing factor may consist of anatomical variants which render the median nerve unusually vulnerable to conditions of stress.

Dr. George S. Phalen [48] said that he had never been impressed with the effect of exercise alone in the production of the carpal-tunnel syndrome. He has a series of over 100 cases in which there is no history of any antecedent trauma or any occupational use of the hand which might predispose to the development of this syndrome. He said that Dr. Tanzer's observations on pressures within the carpal tunnel show why the wrist flexion test is such a good diagnostic sign. In performing this test, the physician asks the patient to keep both wrists flexed completely for thirty to sixty seconds. When the wrist is flexed, the median nerve is squeezed between the proximal edge of the transverse carpal ligament and the flexor tendons. If the median nerve is already a little swollen and tight in the carpal tunnel, the position of flexion of the wrist will almost always increase the numbness, tingling, or pain in the median distribution in the hand.

Dr. Phalen said he was convinced that the major etiological factor in the carpal-tunnel syndrome is chronic tenosynovitis of the flexor synovial membrane in the carpal tunnel. At the time of operation, he had found the flexor synovial membrane to be thickened in almost every patient. He had done biopsies of the flexor synovial membrane, and in over 50 per cent of the cases, the microscopic picture was compatible with rheumatoid synovitis. In his series of patients with carpal-tunnel syndrome, six also had an associated

44. 2799 West Grand Boulevard, Detroit, Michigan.
45. Henry Ford Hospital, Detroit, Michigan.
46. 477 First Avenue, New York 16, N. Y.
47. Hitchcock Clinic, Hanover, New Hampshire.
48. 2020 East 93rd Street, Cleveland 6, Ohio.

trigger-finger, one had de Quervain's disease, two had tennis-elbow, and one had an acute pisiform bursitis. All of these conditions are believed to be largely rheumatic in origin. Furthermore, injections of hydrocortone into the carpal tunnel will often give great relief to the patient. He thought this is due to a reduction in the swelling of the flexor synovial membrane.

DR. EMANUEL B. KAPLAN [49] said that, a certain time ago, he had described a fat pad that is located in the carpal tunnel. This exists in man. This fat pad may be hypertrophied and when hypertrophied it may very well produce the symptoms of this syndrome.

Excision of the Greater Multangular Bone in Mobilization of the Thumb. DR. J. LEONARD GOLDNER [49] and DR. FRANK W. CLIPPINGER presented an interesting paper on mobilization of the thumb by means of excision of the greater multangular. Deformity at the base of the thumb may be due to osteoarthritis, rheumatoid arthritis, or traumatic arthrosis of the carpometacarpal articulation of the thumb with resulting pain and limitation of abduction and internal rotation. The pain and grating may be persistent, not responding to injection therapy and periods of immobilization. If roentgenographic evidence of joint degeneration is present, excision of the greater multangular and, if necessary, the proximal portion of the first metacarpal, will result in relief of pain, increase in the range of motion, and improved use of the thumb.

These same principles of treatment were applied to thumbs with adduction contracture resulting from direct trauma to the hand, trauma to the base of the thumb, or indirectly from trauma to the wrist, forearm, or upper arm. The procedure selected to relieve the adduction contracture depends on the degree of soft-tissue contracture, the extent of fixation at the base of the thumb, and the condition of the remainder of the hand. Three patients with degenerative arthritis and fifteen patients with adduction deformity due to trauma were treated by arthroplasty at the base of the thumb which included excision of the greater multangular and a portion of the base of the first metacarpal for arthritis, and soft-tissue release along with arthroplasty and occasionally skin-grafting for conditions resulting from trauma.

The necessity for doing soft-tissue release or skin-grafting along with arthroplasty depends on the degree of contracture at the base of the thumb and the extent of soft-tissue contracture. The goal is to increase the range of motion, avoid arthrodesis, relieve pain, and open the web so that tendon-transfer procedures, if necessary, may be done on a movable thumb.

First-degree fixation at the base of the thumb requires complete excision of the greater multangular and partial excision of the base of the first metacarpal after release of the capsule, ligaments, and superficial and deep fascia which have not allowed adequate rotation of the metacarpal. Arthroplasty alone will improve the range of motion, relieve pain, and avoid the necessity of skin-grafting. Second-degree contracture at the base of the thumb may require arthroplasty along with split-skin graft. This is particularly true if there has been direct trauma to the base of the thumb with only moderate soft-tissue contracture in the web. Third-degree contracture may require arthroplasty as well as abdominal pedicle flap in the web. Usually capsulotomy of the carpometacarpal joint, complete soft-tissue release, and application of a flap will allow enlargement of the web without arthroplasty. Occasionally, however, the range of motion is improved considerably by excision of the greater multangular.

Stability of the thumb following excision of the greater multangular is usually good. The metacarpal may drift back and articulate with the navicular or the radial styloid process with little change in the normal configuration of the hand. The thumb usually becomes stable, pain is relieved, and strength is usually improved. If trauma to the base of the hand has been direct and severe, such as that seen with a shotgun wound, fibrosis and fixation may recur following arthroplasty although the thumb will be maintained in the abducted position with an adequate web.

Improvement was noted in all hands treated in this way, some better than others. In the twenty-one patients reviewed, this procedure resulted in hands which are more flexible and have usually required less surgery than those in which arthrodesis or routine abdominal flap were done.

DR. T. CAMPBELL THOMPSON [50] commented on other methods which might have been used and discussed the problem in general terms. He wondered if the authors might not have obtained the same results with perhaps more accuracy and with less loss of power, with careful osteotomy at the base of the first metacarpal. He feels that the procedure is certainly much simpler and quicker than an arthrodesis.

Correction of Chronic Dorsal Subluxation of the Proximal Interphalangeal Joint by Means of a Criss-Cross Volar Graft. DR. JOHN P. ADAMS [51] presented a review of the procedures that have been utilized in the past for the correction of posterior subluxation of the proximal interphalangeal joint of the finger. He presented three cases in which a different technique of volar plate substitution was utilized. The following technique was presented. The joint was approached through two dorsolateral incisions three centimeters in length. Lateral bands were retracted dorsally and the flexor sheath was separated from the

49. Duke Hospital, Durham, North Carolina.
50. 341 East 42nd Street, New York 17, N. Y.
51. George Washington University School of Medicine, Washington, D. C.

joint. Transverse drill holes were then placed just proximal to the articular surface and at right angles to the long axes of the bones. Through these holes was threaded a section of previously removed tendon approximately two millimeters in width and ten centimeters in length. The tendon was sutured so that the suture in place was in the shape of a figure eight. The tension was such that the joint was held in 30 degrees of flexion. Three weeks of postoperative immobilization was carried out. Follow-up slides of the three cases were shown.

Dr. Lot D. Howard, Jr., said, in discussion, that cases of recurvatum following hyperextension injuries have always interested him since most of these injuries usually end as flexion contractures rather than recurvatum. A similar paradox is the occasional case of a mid-volar longitudinal scar in the finger which does not end as a flexion contracture.

He thought that he had found the answer after operating on two patients with injuries involving the little finger. In both, the volar rupture had entered the flexor-tendon sheath, and, on inspection, the torn capsular edges had been rounded off like the end of a tendon when cut in its sheath. Free communication between the joint and the flexor sheath was present. Thus the capsule did not heal by scarring.

Treatment, in the case of the little finger, where the sublimis is of minor importance, is simplified by severing this tendon a short distance proximal to the joint. The distal portion, split into its two halves, already has attachment at the proper place on the middle phalanx so they are simply crossed in front of the joint and anchored, either to the cut edge of the fibrous flexor sheath, or, if preferred, put through a drill hole at the end of the proximal phalanx.

For other than the little finger, however, sacrifice of sublimis action seems hardly warranted.

In another patient he had separated the lateral bands in each side and displaced them volarward, scarifying them a bit at the time so they would stick. The recurvatum was cured, but lateral band function was lost. A second operation replaced both the lateral bands and the recurvatum.

Experiences with a New Finger-Joint Prosthesis. Lt. Col. Earl W. Brannon [52] and Dr. Gerold Klein described a new metal hinge-type prosthesis which was developed to replace irreparably damaged joints of the finger. This had been used in selected cases as an alternative to amputation or arthrodesis. This salvage operation was performed in the hope of restoring some degree of useful function in an otherwise useless part.

The prosthesis is a replica of the normal joint and replaces the entire joint. It is fabricated of titanium, consists of two parts joined by a simple hinge which is locked by a half-threaded rivet screw. Each part has a triangular intramedullary stem for insertion into the bones. The device is designed to prevent residual rotation and instability of the finger.

Prerequisites for the procedure are functional or functionally restorable tendons, intact nerve supply, and adequate circulation of the part.

Fourteen patients were operated upon. All had joint defects secondary to trauma and the time interval between injury and operation varied from three months to two years. Twelve proximal interphalangeal joints and two metacarpophalangeal joints were involved. Three patients had concomitant extensor-tendon injuries requiring repair.

Over-all results were gratifying. Results in two patients were discounted because of insufficient follow-up period. The other twelve patients had follow-up periods ranging from ten to thirty-nine months. Results in two of these were regarded as failures because of residual bone resorption and stiffness. The remaining ten patients retained a functional range of painless motion. Stability of the finger and the prosthesis was generally excellent. All patients returned to military duty after a short hospital stay and were engaged in specific occupations requiring use of their hands. Slides of representative cases were shown. The results in this brief series were sufficiently encouraging to warrant further attempts at this method of replacement arthroplasty.

Dr. Joseph H. Boyes [34] stated that he had approached the problem from a slightly different standpoint. He showed slides of several patients in whom a prosthesis had been used. His prosthesis, however, did not attempt to duplicate exactly the size and shape of the joint. It was a simple type of hinge apparatus that could be inserted into the phalanx. One case was demonstrated in which the prosthesis had been inserted into the middle joint. This was in a patient with a fracture-dislocation in this area but without tendon or nerve damage. The result seven months after the insertion of the prosthesis showed excellent motion.

Shortening the Forearm for Serious Soft-Tissue Loss About the Wrist. Dr. H. Minor Nichols [53] pointed out that the loss of more than a small amount of skin and underlying soft tissues in the region of the wrist constitutes a serious problem. Often the problem can be adequately overcome by the application of an immediate skin graft, using local rotation flaps, free skin grafts, or pedicle grafts from the body, to be followed later by definitive surgery on tendon and nerves.

52. 122 Sunnycrest Drive, San Antonio, Texas.
53. 232 Medical Arts Building, Portland 5, Oregon.

In certain cases of defects about the wrist he had found the bone-shortening procedure to be much more efficacious than the more complicated and tedious one of pedicle-flap application with its attending complications.

The presence of a fracture may be the deciding factor against the use of an abdominal flap. However, an osteotomy and removal of a section of bone or removal of more bone at the fracture site may enable the soft tissues to be satisfactorily approximated, obviating the use of flaps and grafts.

This principle should also be followed in replacing an extremity which has been freshly amputated or nearly amputated.

Dr. Raymond M. Curtis [2] said that Dr. Nichols' suggestion of shortening the radius and ulna, in order to achieve an anastomosis of the radial and ulnar arteries, may allow us to achieve a functional hand which otherwise would have had to be amputated.

THE RUSSELL A. HIBBS SOCIETY

As Reported by Nicholas J. Giannestras, M.D., Cincinnati, Ohio

The Tenth Annual Meeting of The Russell A. Hibbs Society was held in New York City Thursday, June 6, 1957. Dr. Frank Stinchfield was in the chair.

Dr. Stinchfield reported for the committee which was appointed to look into the proper dispensing of the Russell Hibbs Fund for worth-while projects. The committee, consisting of Dr. Stinchfield, *Chairman*, Dr. J. Neill Garber, and Dr. Herbert Pedersen, recommended that The Society offer an annual prize of fifty dollars for the best movie presented in the Audio-Visual Program of the Annual Meeting of The American Academy of Orthopaedic Surgeons, hoping that this fund will be increased. The winner is to be selected by the Audio-Visual Committee.

Dr. Stinchfield requested that he be relieved as Chairman of the Membership Committee and that Dr. Frederick Thompson be reappointed to this position since Dr. Thompson's health now permits him to resume his usual activities.

Dr. J. Neill Garber was elected President, and Dr. Nicholas J. Giannestras Secretary-Treasurer; the next meeting will take place in Indianapolis, Indiana, during the spring of 1958.

Résumés of the papers presented follow:

Tumors of the Peripheral Nerves. Dr. Arthur Purdy Stout [1] stated that there are only three varieties of tumors arising from the peripheral nerves of clinical importance. These are (1) the specific encapsulated nerve-sheath tumor or neurilemoma; (2) the neurofibroma, associated with von Recklinghausen's disease; and (3) the malignant nerve tumor which may be either schwannoma or neuro-epithelioma. The neurilemoma is either round or slightly oval. If it lies within a large nerve it tends to spread the nerve bundles apart so that they course over its surface. Dr. Stout said that it is quite safe to spare all nerve bundles in removal even if some of the capsule is left. The malignant tumors tend to spread inside the sheath, producing an elongated fusiform enlargement. In some malignant cases, it was stated that the tumor remains within the sheath but extends toward and finally into the cord, producing paraplegia and death. In other cases the epineurium is ruptured and the tumor infiltrates outside the nerve. Such tumors kill by metastases through blood vessels and lymphatics. Dr. Stout pointed out that von Recklinghausen's disease, protean in its manifestations, produces lesions in the skin, the peripheral and central nervous system, the bones, and elsewhere. The neurofibroma is its most characteristic lesion. These can produce multiple skin nodules, elephantiac skin enlargements, plexiform nerve lengthenings, and encapsulated nerve-sheath tumors. He also said that about half of the malignant nerve tumors are found in patients with von Recklinghausen's disease.

Familial Dysautonomia. Dr. Conrad M. Riley [2] reported that familial dysautonomia is a recently recognized syndrome characterized by specific dysfunction of the entire nervous system, although the disturbances of the autonomic nervous system are the most striking. Some of the features outlined are: failure to produce tears when crying, excessive perspiration and transient skin blotching, drooling, postural hypotension, and often transient hypertension. There is also emotional instability and the patients show poor motor coordination and hyporeflexia or areflexia. There is characteristically a relative indifference to pain, and corneal anaesthesia is the rule. Statistics on the occurrence of the condition in siblings make it likely that it is a recessive trait. So far it has been seen almost exclusively in Jewish families.

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Dr. Riley pointed out that disturbances in the musculoskeletal system in these patients seem to be much more frequent than in the normal population. The fairly high incidence of scoliosis and the few examples of kyphosis may be attributable to neuromuscular imbalance. Several of the children had tibial torsion and muscular imbalance in the feet. The indifference to pain makes the incidence of bone fractures high. An example of Legg-Perthe's disease and of Köhler's bone disease were noted. There was also in this group one patient with congenital dislocation of the hip.

Thus, it was concluded, it is likely that such patients will be seen by the orthopaedic surgeon, who should know about the condition both because he may be first to suggest the diagnosis, and also because, if operative procedures are needed, he should be aware that these patients are poor anaesthetic risks.

Problems in Hypercalcaemia. Dr. Calvin H. Plimpton [3] stated that despite the experiments in hypercalcaemia provided by nature, we have relatively little understanding of its pathogenesis. The symptoms which lead one to suspect hypercalcaemia are neuropsychiatric manifestations from mild lassitude to frank psychoses, gastro-intestinal or renal disorders, or, rarely metastatic calcifications.

It was pointed out that in patients with hyperparathyroidism, the direct action of the parathyroid hormone on bone appears an adequate explanation for hypercalcaemia. In the excessive-milk-and-alkali syndrome, hypercalcaemia seems to depend not only on increased ingestion, but also upon some impairment of renal function. In vitamin-D intoxication, hypercalcaemia can occur in animals on a calcium-free diet. Furthermore, in view of the limited ability of vitamin D to increase absorption of calcium, and its almost unlimited ability when given in large amounts to demineralize bone, the hypercalcaemia is presumably a result of the direct action on bone. It was noted that the hypercalcaemia in Boeck's sarcoid is associated with a lowered fecal calcium, and that it has been postulated that a kind of vitamin-D intoxication with abnormal absorption is present. Reasons were presented for feeling that this may be over-simplification.

Finally, the hypercalcaemia connected with metastatic malignancy was discussed. This condition has been ascribed to destruction of bone by tumor with release of calcium. An interesting group of cases of hypercalcaemia with no demonstrable bone metastasis, and with a dramatic fall in the serum calcium on removal of the tumor was brought up. This situation occurred with a wide variety of tumors, none apparently directly related to bone or calcium metabolism. The mechanism is not clear. It was assumed that the tumor produces some substance which mobilizes calcium and it was suggested that this mechanism may contribute to hypercalcaemia in patients with tumors and bone metastases as well.

The Frozen Shoulder. Dr. H. L. McLaughlin [4] said that the frozen shoulder is complex because it cuts across all branches of medicine while remaining within the sole jurisdiction of none. Many cases tend to be self-limiting, while others are intractable. The clinical picture of many established cases is consistently confused by pseudoneurological and vasomotor sequelae.

He stated that understanding the syndrome is simplified by the realization that the shoulder responds to disuse as does any other joint, that no shoulder will stiffen if mobility is consciously maintained, and that the immediate cause of every stiff shoulder is prolonged dependency of the arm. There are numerous primary causes of prolonged dependency. These may be intrinsic, unconnected with the shoulder, or idiopathic. Regardless of the primary cause, disuse, dependency, and prolonged stress are common to the end result.

It was pointed out that histological changes in the tissues of the shoulder, with the exception of occasional proliferative synovitis, are sparse. Bicipital tenosynovitis when present is an extension of joint synovitis. Cuff tears are notable for the absence rather than the presence of stiffness. A painful acromioclavicular joint often proves to be the primary offending lesion.

Shoulder Prosthesis. Dr. Charles S. Neer II [5] discussed the results of the use of articular replacement when the humeral head had been destroyed in twenty-four patients. The postoperative recovery period had been shortened, and the shoulders stronger, more comfortable, and more movable than those in a comparable group of patients whose shoulders had been resected. The immediate and late indications for the prosthesis were discussed in detail. Three patients were presented for examination, one of whom had been followed for four and one-half years, another for three years, and the third for eighteen months. These patients were symptom-free and two of them had full range of glenohumeral motion.

Restoration of Flexion to the Paralyzed Elbow. Dr. Robert E. Carroll [6] presented an account of his experiences in restoring the power of flexion to the elbow when no power had existed. The most common operation employed was the Steindler flexorplasty. The technique of operation was discussed. Insertion of the medial epicondyle on the anterior portion of the distal end of the humerus was advised. Should a prona-

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tion deformity of the forearm develop following operation, transplantation of the flexor carpi ulnaris tendon was advised and the technique of this operation was discussed.

The technique of transplantation of the triceps around the humerus to produce elbow flexion was described. His experience was that this operation proved excellent in six cases; the longest follow-up was seven years.

The author's experience with the sternocleidomastoid transfer to produce elbow flexion was also described. The technique of the operation was outlined in drawings.

Hip Dysplasia. Dr. Charles T. Ryder [7] reported that because of the importance of early diagnosis in congenital hip disease, orthopaedic surgeons are seeing infants who have unequal abduction, extra skin folds, and even high acetabular angles, but whose hips do not show displacement on roentgenographic examination.

Fifteen hundred children were examined clinically and roentgenographically at birth, six months, and one year of age. Preliminary analysis showed that in infants, truly symmetrical skin folds are less common than asymmetrical or extra folds, instability in the sense of springiness or clicking, may be found in about 7 per cent of hips, and unequal abduction (a positive Hart sign) is present in about 4 per cent. Infants with these findings were not treated; all had normal hips at one year of age. Unilateral subluxations developed in two girls between the sixth and eighth month; neither had shown any clinical or roentgenographic abnormality at birth.

Acetabular-angle measurements followed a normal frequency distribution curve, the mean value at birth being about 28 degrees. In children with high acetabular angles normal hips developed. If clinical examination of an infant's hips shows any definitely abnormal sign, the author advised roentgenographic examination. If no displacement is seen on the roentgenograms, and if other cause for the sign can be excluded (for example, spastic paralysis), one has every reason to anticipate a normal development of the hip joints. Careful observation is of course in order.

Roentgenographic and Clinical Signs of Gargoylism. Dr. John Caffey [8] demonstrated the clinical findings in gargoylism in a boy eight years of age. It was pointed out that persons with gargoylism are often brought first to orthopaedic surgeons because of the stiffness and limitation of motion at the joints. Many of these patients have lumbar kyphosis, often an early clinical sign. In this patient, these features were prominent at the shoulders, elbows, wrists, and in the fingers.

The classic roentgenographic features of gargoylism were shown in lantern slides. It was emphasized that the bone changes are due largely to failure of proper tubulation of the shafts and that there is only minor dysplasia at the junction of the cartilage with the shaft. The hook vertebra which is responsible for the kyphosis was discussed in detail and herniation of the nucleus pulposus was offered as the probable causal mechanism. The early evolution of the changes in the shafts was demonstrated in three infants with gargoylism. The varus deformity at the proximal end of the humerus was shown in both early and late phases of its development.

Current Concepts of Bone Formation. Dr. C. Andrew L. Bassett [9] reviewed recently recorded data on some mechanisms of bone formation. Osseous matrix and the nature of its main components, apatite, collagen, and mucopolysaccharides were explored. By functioning in part as an ion-exchange column, bone maintains an equilibrium between ions of the apatite and the tissue fluids. In order to demonstrate production of osseous matrix by osteogenic cells, the histological phases of incorporation of cortical-bone grafts were reviewed. Evidence was then advanced to show that the osteoblast is capable of elaborating both the mucopolysaccharide and collagenic components of bone matrix. Metachromasia and increased radioactive-sulphate concentration in areas of new-bone formation are indirect indications of mucopolysaccharide production by osteoblasts. In addition, electron microscopy has linked the osteogenic cell with elaboration of collagen fibers or their precursors. Finally, to complete the picture of a calcified matrix, the early and late phases of apatite deposition were demonstrated as they appear under the electron microscope.

Diastematomyelia. Dr. James B. Campbell [10] described the morphology of diastematomyelia. The origin of the malformation was considered in the light of theoretical embryology and the experimental work of Detwiler. Diagnostic criteria derived from physical and roentgenographic examinations were enumerated before the general indications for neurosurgical interference and corrective orthopaedic measures were discussed. Details of roentgenographic techniques were illustrated by photographs. The successive steps in the removal of the bone spicules were similarly illustrated. These were situated in the bifid spinal cords of individuals who had been treated for this condition.

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Further Advances in Vertebral-Body Biopsy. Dr. Frederick S. Craig [11] reported that it has been stated that biopsy above the ninth thoracic vertebra is not advised because of the azygous and hemiazygous systems[c]. However, the author felt that specimens from all of the thoracic vertebrae may be obtained by a meticulous approach well controlled by anteroposterior and lateral roentgenograms. The instruments and technique were reviewed [a,b]. A slide of the cross-section anatomy at the level of the fifth thoracic vertebra was shown to demonstrate the retropleural placement of the needle and trocar. Roentgenograms made during the procedures were shown to demonstrate the successful biopsy of the fifth thoracic vertebra on one patient and of the fourth thoracic vertebra on another. There were no complications.

Discograms of a third patient at the third, fourth and fifth lumbar vertebrae were shown. A simultaneous biopsy of a sclerotic section of the fourth lumbar vertebra was done. There was no risk of leakage of diodrast into the neural canal. The sterile-tray method as used in the author's biopsies was demonstrated.

a. Craig, F. S.: The Craig Vertebral Body Biopsy. New York State J. Med., **55**: 3422–3424, 1955.
b. Craig, F. S.: Vertebral-Body Biopsy. J. Bone and Joint Surg., **38-A**: 93–102, Jan. 1956.
c. Valls, José; Ottolenghi, C. E.; and Schajowicz, Fritz: Aspiration Biopsy in Diagnosis of Lesions of Vertebral Bodies. J. Am. Med. Assn., **136**: 376–382, 1948.

Special Problems in Disc Disease. Dr. E. B. Schlesinger [12] analyzed causes of failure following disc removal and fusion in thirty-eight patients. Technical factors included failure to recognize complicating anatomical variants such as less than normal interpedicular spacing, with an extremely narrow spinal canal in the side-to-side diameter. This anomalous type of spine is associated with small interspaces, extremely crowded lateral position of the involved nerve root, and presentation of the dura of the canal proper under the ligamentum flavum at the interspace, thus increasing the vulnerability of the dura. It was pointed out that in the difficult exploration for the laterally placed lesion, trauma to the dura leads to scarring and cicatrix formation and not infrequently to the formation of traumatic meningoceles at the site. In a similar way, the less common narrow anteroposterior diameter of the canal leads to operative difficulty. Here there is flattening out and compression of the dura, along with great thickening of the overlying bone structures and small interspaces. The author said that the unaccustomed location of the intracanal structures leads to trauma similar to that described with narrow lateral diameters.

He discussed a second group composed of patients in whom exploration is difficult due to excessive bleeding. In these patients there was serious increase in the venous pressure within the extradural circulation in the prone position. A rapid drop in pressure had been effected by placing the patients in positions designed to prevent abdominal compression during operation. Other causes of increased venous pressure were discussed, including the effect of poor respiratory excursion and carbon-dioxide retention. The worst problems occurred when positive pressure was maintained against the expiratory phase of breathing. Here the bleeding was as difficult a problem as when there was direct compression of the abdomen. Several of the thirty-eight patients who had had disc and fusion operations were shown to have had an erroneous diagnosis; the true pathological entity consisted in occlusion of the lower end of the aorta or of the iliac vessels. It was pointed out that examination at all times should include a careful study of the circulation since circulatory disorders such as those discussed can mask themselves as mechanical low-back problems. Arthritic spurring may cause nerve-root compression to a crippling degree. A group of patients was described in whom successful disc and fusion operations were followed by cephalad progression of the fulcrum of motion with degenerative change at the next higher interspace. These patients are prone to dramatic nerve-root compression. One patient returned a year following his successful operation with complete drop-foot which followed two weeks of severe back pain.

Surgical Procedures in Cerebral Palsy. Dr. D. Keith McElroy [13] reported that the relative incidence of cerebral palsy is increasing as poliomyelitis is being brought under control. There are four times as many cerebral palsy cases as there are of scoliosis. Sixty per cent of these patients have intelligence quotients below seventy but this is no contra-indication to surgery if there is a reasonable hope that operative intervention will increase self-care, the author said. Premature birth is a predominant etiological factor. Ninety-eight per cent of the operations are done on spastic patients as against those done on athetoid and ataxic patients. Ninety-eight per cent are done on the lower extremities. Some degree of dislocation of the hips is present in 9 per cent of the patients. Adductor tenotomy with obturator neurectomy is the most common procedure about the hip. It was pointed out that derotational osteotomy of the femur is being performed with increasing frequency.

The most frequently successful procedure at the knee level is hamstring transplantation. The original Eggers procedure has been modified by transplanting only the semitendinosus and biceps femoris. These are inserted through a drill hole in the distal portion of the femur and then secured one to the other with the hip in maximum extension. The hip spica applied at the time of surgery remains *in situ* for eight weeks.

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Gastrocnemius neurectomy was felt to be indicated for talipes equinus if the heels drop down to the floor when the patient stands. If not, an aponeurotomy of the Vulpius type is performed. A walking plaster is maintained for a minimum of eight weeks. A night brace was said to be desirable for several years. The author said that Achilles-tendon lengthening should not be performed at the same time as neurectomy or muscle transplantation. Operative intervention should be carried out before the development of fixed contractures and deformities.

It was stated that additional procedures are sometimes necessary for recurrence of talipes equinus in children, but rarely after the age of fourteen. Transplantation of the tibialis posterior to the middle cuneiform is one of the most successful procedures in cerebral palsy in the lower extremity. The muscle is transposed through the interosseous membrane. This operation was said to be feasible even with some fixed talipes equinus as assessed with the patient awake. In older children roentgenograms should be made to determine if the body of the talus presents a flat top. Originally in a few of these transplantations, the tendon was inserted into the cuboid in patients with extreme varus deformity. This was an error since severe valgus deformity developed in almost all of these patients, the author stated. In the upper extremity the best procedure was felt to be arthrodesis of the wrist joint. Prior to bone maturation excellent results by transplantation of the flexor carpi ulnaris to the extensor carpi radialis longus were reported.

SOUTHERN MEDICAL ASSOCIATION

SECTION ON ORTHOPAEDIC AND TRAUMATIC SURGERY

AS PREPARED BY DANIEL C. RIORDAN, M.D., *Secretary*, NEW ORLEANS, LOUISIANA

The Fifty-First Annual Meeting of the Southern Medical Association was held in Miami Beach, Florida, November 11 to 14, 1957. Summaries of the papers read at the sessions of the Section on Orthopaedic and Traumatic Surgery follow:

The Use and Abuse of the Jewett Nail Plate in the Treatment of Fractures of the Hip. DR. MAXWELL H. BLOOMBERG [1] discussed the technical procedures in the use of the Jewett nail plate in the treatment of fractures of the hip. The author emphasized the importance of properly applying the nail plate to the hip after the fracture had been well reduced, in order to retain the fragments in solid apposition. With proper alignment of the fragments, early ambulation was possible.

The author pointed out several abuses in the use of this nail plate: poor selection of the proper angle of the nail plate; a nail that is either too long or too short; forceful adaptation of the plate to the shaft of the femur resulting in extrusion of the screws with loss of angle during weight-bearing; re-application of a poorly centered nail resulting in a widened channel, poor stability, and the possibility of development of a necrotic femoral head.

The author recommended that the patient be seated in a wheel chair within twenty-four hours, allowed to stand alongside the bed in forty-eight hours, and to use a walker within four or five days. An active rehabilitation program is followed thereafter.

Failure of Two-Piece Nail-Plate Fixation for Intertrochanteric and Subtrochanteric Fractures of the Hip. DR. MARVIN GIBSON [2] stated that he collected eighteen mechanical failures in the use of fixation devices for fractures about the trochanters. Fifteen of the failures occurred in McLaughlin and Thornton combination nail plates. Five McLaughlin nail plates failed because three of the screw extensions from the nail and one joining cuff of the plate broke, and one joining screw loosened. Ten Thornton nail plates failed because of five loose joining screws, three broken screws, one nail with stripped threads, and one plate which broke at the nail junction. The author felt all but the last failure were due to obvious weaknesses of the devices. Two Jewett nail plates and one blade plate also broke at the nail junction.

The author felt a one-piece dropped-forge device like the Jewett nail plate is stronger than a device consisting of pieces screwed together. The strength of the Thornton and McLaughlin nails depends on the thread of the joining screw or nut, the cuff on the proximal end of the plate, and the human skill that joins the device together.

The author concluded with the suggestion that standards of strength for our internal-fixation devices be established.

Paralytic-Hip Dislocation. DR. DARIUS FLINCHUM [3] said that correction of associated external femoral torsion by supracondylar rotation osteotomy was found valuable in giving stability to patients with paralytic-hip dislocation. The disorder should be detected early by clinical examination and if the hip is found stable

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when held in internal rotation, a derotation osteotomy should be performed before much laxity develops about the hip joint. Some internal rotator muscle power is desirable for a successful outcome. An internal rotator elastic strap attached from a toe-to-groin brace to a corset is beneficial. The author proposed that release of hip adductors might be considered to improve the unfavorable muscle imbalance of stronger adductors and external rotators which are usually present in this specific disorder.

Femoral-Head Replacement as a Salvage Procedure. Dr. Philip J. Fagan [4] and Dr. Arabion N. Taylor [5] discussed femoral-head replacement as a salvage procedure for elderly patients, following any type of fracture of the femoral neck in which early primary union is doubtful, when primary treatment has failed, or when failure appears to be inevitable. There are no systemic contra-indications to this operation if the patient was ambulatory prior to fracture of the femoral neck. The acetabulum should be relatively normal for the age of the patient and there should be no marked deformity of the femoral head or neck. The patient must have a desire to live.

The authors stressed the following important operative techniques: there must be adequate exposure, preferably the Gibson-type approach; the abductors should be detached near the greater trochanter; the joint capsule should be opened widely on the anterior side, but not resected; the prosthesis (approximately same size as head removed) should be placed in abduction with adequate neck length; the acetabulum should not be reamed, the joint capsule should be closed snugly; and the abductors should be fixed securely to the greater trochanter.

Postoperatively, the lower extremities are maintained in abduction, and three or four pillows are placed between the knees. Abduction exercises with a skate are begun in three to seven days, and ambulation in an invalid walker begun one to three weeks postoperatively. The authors reported that eleven of the sixteen patients with a follow-up study of six months to three and one-half years are ambulatory with the aid of a cane.

Bone Reaction to Stainless-Steel Fixation Material. Dr. John E. Burch [6] discussed the effects of electrolytic reaction of metallic devices for osteosynthesis in orthopaedic surgery. In spite of a previous careful investigation by Venable and Stuck, we are still experiencing cases in which the fault undoubtedly lies in the manufacture of the device and not in the technique of the surgeon nor in the carelessness of an operating-room nurse.

The author presented several instances of electrolytic reaction in bone as the result of the use of metallic appliances for internal fixation. These appliances were labeled and understood to be stainless or rustless steel.

In the event an open procedure is decided upon and a metallic fixation device is to be used, the author felt that every effort must be made to make sure that the same type of metal in both plate and screw or other device is used. Orthopaedic surgeons should be constantly seeking metallic appliances that are neutral in human-body fluids and that do not produce an electrolytic reaction and chronic pain or disability in the patient.

Central Dislocation Arthroplasty of the Hip. Dr. Hanes T. Brindley [7] discussed the three major factors to consider in reconstructive surgery of the hip. They are pain, stability, and motion. Of these factors elimination of pain is by far the most important.

Attempts have been made to eliminate the pain by interfering with the innervation of the hip through neurectomies and capsulectomies. These have given some relief of discomfort, but generally have been unsatisfactory. The author reviewed several other methods of reconstructive surgery of the hip. The author felt that in all these procedures very little had been done to the acetabulum.

In 1948, Charnley first did his central dislocation procedure for the hip. In this, a defect was made in the acetabulum through which the head of the femur was placed. This method gave a more rapid and surer method of producing sound arthrodesis. The author discussed Charnley's technique and results and enumerated four major mechanical changes in the procedure.

The author gave a preliminary report of the results of four central dislocation procedures as a type of arthroplasty. The early results were very gratifying. There was remarkable relief of pain in these patients and the stability was good. There was no Trendelenburg sign even when the patients first started walking seven to eight weeks postoperatively. Motion is very limited and, as pointed out by Charnley, probably should not be more than 40 per cent of normal if an ideal result is to be obtained. These patients were hospitalized from six to eight weeks; one of them returned to strenuous labor at three months. The author felt it is important to make the defect in the floor of the acetabulum anterior and superior if a good position and seating of the head and neck of the femur are to be obtained. He believes that this procedure is another that should be added to the armamentarium of hip surgery.

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Pathological and Clinical Aspects of Osgood-Schlatter's Disease. Dr. Ira H. Rapp[8] and Dr. Gordon D. LaZerte [9] reported a study based upon the correlation between the clinical and pathological aspects of Osgood-Schlatter's disease. Nineteen histological specimens from seventeen patients were studied; these sections demonstrated that the fundamental lesion is a pathological intratendinous process in which fragments of cartilage and bone have been displaced from the developing apophysis of the proximal tibial epiphysis.

The authors said that clinical signs and symptoms arise from increasing intratendinous pressure produced by excessive strain at the insertion of the patellar ligament. This is due to physical activity during a period of rapid linear skeletal growth. In a more advanced stage, cartilage and bone ossicles are demonstrable. These may later exhibit autonomous metaplastic growth.

The initial roentgenographic findings included soft-tissue swelling and loss of definition at the insertion of the patellar ligament. During the more advanced stages, bone fragments were demonstrated along with bone proliferation.

Since the process is one of intratendinous pressure, the author recommended that conservative measures of restricted activity and immobilization be attempted. If, however, conservative therapy fails, relief of pressure can be obtained through the removal of intratendinous ossicles.

Muscle-Pedicle Bone Grafts. Dr. Joe B. Davis [10] presented experimental evidence showing that cancellous-bone grafts when attached to muscle-belly origins will maintain viability, making possible healing of fractures in the graft. The muscle attachment furnishes sufficient blood to maintain viability of the bone in the presence of infection.

Attachment of cancellous-bone grafts to muscle bellies can be transferred from one muscle to another and viability of the graft will be maintained. Techniques for transferring these grafts were demonstrated in various locations. At the hip joint the pedicle of the anterior crest of the ilium is composed of the tensor fasciae latae and the glutaeus medius muscle. At the sacro-iliac joint, the posterior crest of the ilium is transferred with a pedicle from the glutaeus maximus and the posterior portion of the glutaeus medius. At the shoulder joint, the acromion is transferred to the shoulder joint and the deltoid is used as a pedicle. Transfer of the iliac crest to the site of non-union in the forearm was demonstrated to result in union. This same principle of transfer of viable bone with muscle-belly origins can be applied in selected instances of osteomyelitic defects in which there is a loss of central portions of cancellous area of bone.

Dynamic Roentgenography of the Low Back. Dr. Allen M. Ferry [11] pointed out that routine roentgenograms of the low back are made of the lumbosacral and redundant spine from various angles with the patient in the recumbent position, the position of minimum strain. Probably the majority of such roentgenograms are read as negative, although the clinical picture may suggest a severe low-back pain. Since low-back pain is a condition which is apparently brought on by function of the lower portion of the back, the author felt that a more functional technique of making roentgenograms of the lower portion of the back was logical in order to try to produce information which would be an aid in making diagnoses and localizing the source of the trouble.

Eight years prior the author began to make roentgenograms with the patients in various standing positions in addition to the routine roentgenograms made with the patient recumbent. The additional roentgenograms made standing consisted of an anteroposterior view which gave an immediate evaluation of the position of the hips and pelvis in relation to the lower portion of the back and any possible deviations of the spine such as trunk shift or scoliosis. Lateral roentgenograms were made in what the patient considered his normal standing position. Roentgenograms were also made in extension and in flexion. It is the author's opinion that lateral roentgenograms so made gave valuable information in addition to showing anatomical defects. A comparison of the normal standing position and the extension standing position in a high percentage of cases revealed that the patient habitually stood with complete hyperextension of the lower two or three lumbar joints with resultant narrowing of the posterior joint spaces and neural canals. This habitual position has struck the author as being very significant in the production of the commonly encountered disc-degeneration syndrome which is seen frequently.

In most cases the author noted that in flexion of the spine, which merely flattens out the low back, the posterior joint spaces and the neural canals were opened up, thereby conceivably relieving pressure on the soft-tissue structures. This pointed the way more clearly to prevention as well as relief of disc degeneration and complaints pertaining to the ischium. The presence of muscle spasm in the cervical spine has, for some time, been recognized roentgenographically as a significant and definable condition. Similarly, spasm of the lower portion of the back and fixed contractures of the lumbar vertebral joints may be recognized by the dynamic method of making roentgenograms.

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Lumbar Fasciotomy. Dr. Elias Margo [12] reported a procedure for the release of contracted lumbar fascia. A review of the anatomy of the lumbar fascia was given. This subject was brought to the author's attention seven years ago when he had a patient with extreme lordosis and complaints referable to the ischium following trauma. During surgery the author found that the lumbar fascia was hypertrophied and difficult to retract. It required severance of the deep lumbar fascia between the iliac crests. Following surgery, the patient made a remarkable recovery, had relief of the pain in his back and of a tension type of dull occipital headache.

This procedure was performed on a variety of patients with a history of lordosis and of episodes of pain with stiffness and bed confinement.

The patients treated had prespondylolisthesis, spondylolisthesis, extreme lordosis following healed and ankylosed tuberculosis of the hip, osteomyelitis, and lordosis and hip deformities following cup arthroplasty, Whitman's reconstruction, and malum coxae.

The technique of the operation consisted in a three-inch transverse incision, or slightly downward curved incision, at the lumbosacral level. Electrocoagulation was used to control bleeding. The deep lumbar fascia was cut transversely between the superior iliac spines. When fascial fibers were found taut at the junction with the iliac crests, the dissection was extended proximally along the crests to release tightness. Then the fascia was freed from the fourth and fifth lumbar and first sacral spinous processes. Usually, it was necessary to cut the interspinous ligaments between the fourth and fifth lumbar and the first sacral spinous processes.

The wound was closed with No. 1 plain catgut to the superficial fascia and then with silk to the skin. The patient should remain supine for forty-eight hours.

The results were uniformly good. Lumbar fasciotomies were performed in over 200 patients; the majority of the operations were disc fusions.

Sacro-iliac Changes Associated with Dysfunction of the Spine. Dr. Henry L. Feffer [13] and Dr. John P. Adams [14] reviewed the literature in which roentgenographic change in the sacro-iliac joints has been variously associated with ankylosing spondylitis, pregnancy, brucellosis, paraplegia, aging, obesity, vertebral osteochondritis, spinal tuberculosis, spondylolisthesis, intervertebral-disc herniation, and hip disease. In each, a specific causal relationship rather than a fundamental parallel etiology has been assumed.

Roentgenograms of the sacro-iliac spine of patients whose primary diagnosis included an even greater variety of lesions were presented, and these were found to have a striking similarity with various stages of ankylosing spondylitis. Recognizing the importance of such changes in the early diagnosis of this disease, the authors attempted a comparative analysis of various sacro-iliac abnormalities.

The subchondral condensation early in the disease was not considered unlike that seen associated with mechanical dysfunction in spondylolisthesis, intervertebral-disc herniation, obesity, idiopathic scoliosis, and perhaps osteitis condensans ilii. The joint destruction and ankylosis seen in the late stages of the process were said to resemble changes associated with paraplegia, brucellosis, vertebral tuberculosis, spinal-cord tumor, and aging, and could be related to regional hyperaemia with osteoporosis. The possibility of still other factors, inflammatory in nature, was not ruled out in view of the sparsity of available histopathological data. However, none have yet been demonstrated. The authors are now in the process of collecting additional material and feel that some definite conclusions will be available at a later date.

The authors felt that these facts, along with the absence of significant localized symptoms referable to the sacro-iliac spine in ankylosing spondylitis, suggested that the roentgenographic changes in these joints may be non-specific in etiology rather than a simple manifestation of the rheumatoid process.

Supracondylar Fractures of the Humerus in Children. Dr. Charles J. Frankel [15], Dr. Paul S. Derian [16], Dr. Charles R. Borzilleri [17], and Dr. B. Coughran [18] presented a review of fifty cases of supracondylar fractures of the elbow in children treated over a five-year period. The advantages of Dunlop's traction treatment in selected cases were enumerated and the indications for its application discussed. The recognition of the indications for open surgery was pointed out and the value of conservative treatment emphasized. A case history of one operative treatment was included. This study was aimed at the general practitioner and surgeon rather than the orthopaedic surgeon.

Radial-Nerve Injuries. Dr. J. Leonard Goldner [19] and Dr. James M. Kelley [20] reported specific

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and general principles concerned with radial-nerve injuries based on a study of the records of sixty-three patients. Thirty-nine patients in this group had bone or joint injury with associated radial-nerve damage. The authors discussed both the direct and indirect methods of determining nerve continuity and regeneration, and pointed out that Tinel's sign is a satisfactory, but inconclusive method of estimating the degree of nerve damage in closed fractures of the humerus. Immediate surgical examination of the radial nerve, although usually not necessary, may be beneficial if the nerve is thought to be impaled on a fracture fragment or if it is suspected to be in the fracture site interfering with reduction. However, the patients in the authors' series who had had immediate exploration required two or even three operations on the nerve.

The authors found delayed operation (six to twenty weeks) compatible with satisfactory recovery of muscle function if the nerve was reparable. Neurolysis of an intact nerve, although done frequently in the course of delayed exploration, did not necessarily accelerate the extent or rapidity of muscle recovery. Adequate nerve suture within five months (preferably three months) of the original injury may be expected to give a result superior in both muscle coordination and strength to that obtained by tendon transfer. The authors found that tendon surgery, if performed at the proper time, was quite satisfactory without wrist fusion in restoring adequate function of the hand. Tendon-transfer procedures were delayed if there was any evidence of progressive nerve regeneration or muscle recovery. There appeared to be no indication for tendon transfer during the first few months unless it was certain that the nerve was irreparable. In that case, a tendon transfer should be done as soon as is practical.

The authors found humeral shortening a useful procedure in allowing adequate nerve suture. The physician, when confronted with a radial-nerve injury, should have an over-all plan including the proper time for exploration of the nerve, fracture fixation if necessary, neuroma resection if indicated, humeral shortening, and the ideal time for tendon-transfer procedures. Throughout this entire program, contractures should be prevented, joint motion maintained, and muscle re-education carried out when necessary.

Medullary Nailing of Fractures of the Forearm. Col. Sterling J. Ritchey [21], Capt. James P. Richardson [22], and Col. Milton S. Thompson [23] discussed their experience in the open treatment of thirty fractures of the bones of the forearm with special consideration to the medullary nailing of fractures of the radial shaft from 1951 to 1957. An anatomical discussion was presented concerning the morphology of the medullary canal of the radius in reference to the efficacy of medullary nailing, and a new method of medullary nailing was discussed from the standpoint of anatomical approach, technique, and fixation material. The rigid triangular intramedullary rod was inserted from the dorsum of the radius distally in line with the projected medullary canal of the middle portion of the radius. The rigid fixation material allowed elimination of postoperative plaster immobilization and was conducive to early mobilization and rehabilitation. Analysis of the cases so treated was presented including fracture-healing time.

Shotgun Wounds of the Hand and Wrist. Dr. Lee W. Milford [24] pointed out that shotgun wounds of the hand and wrist are open, untidy, crushing, penetrating, and highly destructive to a very complicated and compact part of the human body. They often involve skin, muscle, tendon, bone, and nerve, and are a formidable challenge to even the most skilled surgeon.

In the face of such acute, severe injury, and with the threat of potential infection, the author felt that one cannot immediately attempt detailed repair. He suggested that surgeons should follow principles which he called the "three Cs"—cleansing, covering, and correct positioning. First, the surgeon should cleanse the wound thoroughly by soap and water, irrigation, and discriminating débridement. Only the judgment of the individual surgeon can determine whether he should attempt initial repair such as re-establishment of the bone framework, often with Kirschner wires, to prevent soft-tissue contractures. The wound should be covered with skin, either local tissue, if available and viable, or from another region. The graft may be a split graft or even a pedicle. Finally, the surgeon should dress the hand with pressure dressings to hold it in the position of function, and the hand should be elevated immediately after surgery.

The author illustrated these three principles with four case reports.

Epiphyseal Fractures of the Tibia and Femur. Dr. Harry R. Brashear [25] realized that fractures involving the epiphyseal plates of long bones form a small but important group of childhood injuries. Because of the danger of deformity secondary to growth disturbance, epiphyseal injuries in the lower extremity are of particular interest. Areas most commonly affected in the lower extremity are the distal portion of the tibia, distal portion of the femur, and proximal portion of the tibia, in order of decreasing frequency. When the clinician is confronted with fractures in these areas, the question of possible future growth disturbance arises. Since the degree of damage to the growing cartilage cells cannot be determined by roentgenograms,

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25. University of North Carolina, Chapel Hill, North Carolina.

the damage to these cells is determined by the amount of force exerted upon them and by the direction taken by the fracture line resulting from that force.

The author reported that epiphyseal fractures were produced in rats and rabbits to study the microscopic anatomy of these injuries and to try to relate these findings to future growth disturbance of the epiphysis. An attempt was made to reproduce, in animals, fractures similar to those occurring in humans.

Rupture of the Long Head of the Biceps Brachii. Dr. Elza F. Butler [26] and Dr. Ronald M. Buck [27] noted that rupture of the proximal tendon of the long head of the biceps brachii is not an uncommon lesion. After reviewing twelve cases, the authors also noted that the diagnosis may be overlooked for some time after the onset of the symptoms of pain about the shoulder. The symptom of pain about the shoulder is frequently regarded as minor both by the patient and the physician. They considered it worth while to call attention to this lesion and to point out the necessity for careful examination when confronted with vague or indefinite symptoms about the shoulder. If an early diagnosis of rupture of the biceps tendon is established, proper repair can be accomplished, and the surgeon is able to maintain good power in the muscle. Repair should be made in all patients except those in the older age group whose activity is already limited. Re-attachment of the proximal end of the muscle to the humerus in a normal line of pull gives satisfactory results and was accomplished without difficulty in the six cases reported by the authors.

Tuberculous Tenosynovitis of Flexor Tendons of the Hand. Dr. Thomas F. Parrish [28] and Dr. Don L. Eyler [29] presented a review of tuberculous tenosynovitis of the flexor tendons of the hand. Since the lesion is infrequent, the principles of treatment are not generally well understood. As soon as the diagnosis is suspected, administration of streptomycin and isonicotinic acid hydrazide should be started, and after one week, radical surgical excision of all the tuberculous granulation tissue in the forearm, hand, and fingers should be accomplished. One should not wait until the late fibrotic stage of the tuberculous infection. At the time of surgery involved tendons must be excised and tendon transplants may be accomplished. Antibiotic therapy should continue for a period of three to six months postoperatively. The authors presented illustrative cases.

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WESTERN ORTHOPEDIC ASSOCIATION

As prepared by the Editorial Committee: George L. Dixon, M.D., *Chairman*, Kirk J. Anderson, M. D. Robert Mazet, Jr., M.D., Ivar J. Larsen, M.D., and John A. Schwartzmann, M.D.

The Twenty-First Annual Meeting of the Western Orthopedic Association was held in Santa Barbara, California, October 20 through October 24, 1957, under the Presidency of Dr. Samuel S. Mathews.

A great deal of emphasis and interest was directed to the Resident-Training Program and the Training Centers in the Western states, both by Dr. Mathews in his Presidential Address, and also by Dr. John A. Schwartzmann, Chairman of the Resident-Training Program.

The Resident-Training-Program Awards, which were named in honor of the originator, Dr. Vernon P. Thompson, were given to the following essayists: First Prize (tied): with $350.00 to Byron M. Shieman, M.D., for "Postoperative Infections in Elective Orthopaedic Surgery;" and an equal amount to James P. Dunlap, M.D., for "Sciatic Nerve Section in the Paraplegic Spina Bifida Patient." Second Prize (tied): with $150.00 to W. R. Murray, M.D., for "Post-Irradiation Fractures of the Femoral Neck;" and an equal amount to Jack L. Lewis, M.D., for "Step-Cut Osteotomy with Intramedullary Fixation for Non-Union of Femoral-Shaft Fractures."

Dr. Joe B. Davis of Portland, Oregon, was installed as President for the ensuing year. The next Annual Meeting will be held in Portland, Oregon, from October 22 through October 25, 1958. Officers elected for 1958 are:

President-Elect: William F. Stanek, M.D., Denver, Colorado.
Vice-President: Faulkner A. Short, M.D., Portland, Oregon.
Secretary: Eldon G. Chuinard, M.D., Portland, Oregon.
Treasurer-Historian (for three years): Walter Scott, M.D., Los Angeles, California.
Editorial Committee (*New Member*): Howard A. Mendelsohn, M.D., Los Angeles, California.

It was decided that the 1959 meeting will be held in Denver, Colorado, under the Presidency of Dr. William F. Stanek.

Summaries of the papers presented follow:

Physiology of the Bone Matrix. Dr. William R. Bergren [1] stated that the inorganic and organic portions of the bone are mutually interdependent and that the chemistry of the organic matrix is just as important as that of the calcification process. When the inorganic portion of bone is dissolved with acid, the remaining model of the bone consists of a coherent elastic material, largely protein in composition.

He reported that electron microscopy shows that bone has a granular structure, due to the organic material being enclosed in the meshes of a very fine network of inorganic material. Only a small amount of the organic fraction is contributed by cells. The chief components of the organic matrix are collagen and, constituting 90 per cent or more of the dry fat-free weight, the ground substance between the fibrils of collagen.

The principal components of the organic matrix were given as (1) collagen, (2) the mucopolysaccharide ground substance, and (3) the glycoprotein reticulin. Treatment of the ground substances of bone matrix by complex staining methods suggested that the ground substances are composed mostly of highly polymerized mucopolysaccharides in contrast to the low polymerization of the mucopolysaccharides in newly formed bone. The function of small quantities of carbohydrates in the ground substances was considered speculative. The function of the ground substance as an interfibrillar cement was noted. It was said to be probably that the protein fibrils of collagen can be maintained in approximation by loose strands of mucopolysaccharide molecules through surface-charge properties of the two types of molecules.

The sulphur content of chondroitin sulphate was emphasized. A study in which isotopic sulphur-labeled methionine was used showed that the labeled sulphur was taken up three to five times faster by healing fractured bones than by control bones. It was found difficult to demonstrate clearly the effect of nutrition on bone growth and fracture healing. Because of the net economy in the body of amino acids, it was not easy to separate direct effects on bone from those involving the total body protein. Deficiencies in dietary intake of some proteins caused some inhibition of bone development experimentally, but it was found that apparently ingestion of extra amino acids does not hasten bone formation.

Osseous Coccidioidal Granuloma: The Measure of Prognosis and Indications of Surgery. Dr. J. P. Conaty [2] reviewed the cases of thirty-one patients with proved osseous lesions of disseminated coccidioidmycosis seen at the Los Angeles County General Hospital during the last ten years. The importance of establishing a diagnosis was emphasized in relation to four main types of the disease in which:

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[2] 1435 North Fullerton Road, Fullerton, California.

1. Rapid, fatal dissemination follows the pulmonary infection. Complement-fixation titers are high in these patients and the prognosis is grave.

2. The patient's general condition is good, there is a single osseous focus only, and complement-fixation titers are low. Surgical extirpation of the focus is advisable and the prognosis is good.

3. The diagnosis is usually not made until after the disease has become disseminated, and complement-fixation titers are correspondingly high. The patient does not appear ill. Surgery is not advisable and no prognosis is made.

4. The disease has been disseminated for from two to ten years and there is no pulmonary activity. There are multiple foci, but because the disease process is in equilibrium, the patient appears well despite high complement-fixation titers. No surgery is indicated. No prognosis is given, but presumably is good.

It was reported that the spinal column and the lower extremities distal to the knee joint are the commonest sites of localization. The author said that appropriate clinical and laboratory methods must be utilized to establish the diagnosis and that surgical extirpation may be curative at any stage of disease.

Further Observations Dealing with Fracture of the Intercondyloid Eminence of the Tibia. Dr. Marvin H. Meyers [3] and Dr. Francis McKeever [4].

Internal Fixation of Explosive or Barrel-Stave Fractures of the Tibial Condyles. Dr. Harle B. Grover [5] described explosive or barrel-stave fractures of the tibial condyles as those that are highly comminuted, previously described by Cotton and Berg as fender fractures. Because of the marked depression of the tibial articular surfaces and stavelike comminution of the cortex of the tibia, these fractures present problems in accurate reduction and internal fixation.

Accurate open reduction of the fracture with grafting to maintain the elevated articular plateau is essential. A method of internal fixation was presented in which a semicircular plate acted as a barrel hoop to hold the fragments in reduction. The plate was maintained by a transfixion bolt through the tibial condyles and a single short screw to prevent rotation of the plate. Two cases were reported. The follow-up on one was a year, on the other, eleven weeks.

Arthroplasty of the Hip. Dr. Floyd Jergesen [6] presented a preliminary report of his clinical studies on interposition arthroplasty of the hip. A review of the historical methods of arthroplasty of the hip failed to disclose reports of extensive studies in which rigid extracortical apparatus attached firmly to the femur were used.

The author described an apparatus in which the head is a spherical segment, hollowed in a cylindrical fashion, and designed to be firmly wedged onto the remodeled head or neck of the femur, interposing a thin wall of metal between the femur and the acetabulum. The base is asymmetrical and bell-shaped, shortened at one pole and flattened in the coronal plane. Superiorly, the base rests on the remodeled femur and provides wide contact between metal and bone. It acts both as a protective shield to the retinacular blood supply beneath and as a guide to the re-formation of the hip-joint cavity.

During a period of four and one-half years, fifty-five patients (sixty-three arthroplasties) were observed. Only two procedures were done for recent fracture of the femoral neck; the remainder were reconstructive and done, generally, in patients with advanced disease. Patients in whom thirty-one arthroplasties had been done were observed for more than two years postoperatively. These early results were discussed primarily with reference to the practicability of the method.

There were three failures as a result of postoperative infection and three due to dislocation of the apparatus from the acetabulum, caused by avoidable factors. Three supplemental operations were carried out to relieve stiffness or pain. The author felt that an objectionable feature of the method was the possibility of loosening or even displacement of the apparatus resulting from absorption in the upper part of the femur. However, evaluation of the preliminary data showed that these complications could be avoided, at least for periods up to four years. He identified controllable factors which cause such loosening and displacement: failure to preserve retinacular and medullary blood supply to the upper part of the femur, inadequate removal of necrotic bone, and failure of graded loading of atrophic bone during convalescence and rehabilitation.

Since his initial experience was favorable, the author concluded that further study of interposition arthroplasty by this method was warranted because it may ultimately prove of value in clinical practice. It was emphasized that the apparatus is not simple to apply and that the reconstructive operation is difficult technically.

Primary Prosthetic Replacement of the Femoral Head in Fresh Intracapsular Fractures of

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[5] 839 Louisiana Street, Vallejo, California.
[6] 384 Post Street, San Francisco, California.

the Femoral Neck. Dr. Joseph B. Tanner [7], Dr. August W. Meier [8], and Dr. William R. Grannis [9] reported sixty Austin Moore femoral-head replacement operations and seven F. R. Thompson replacements done over a period of several years as the primary treatment in fresh intracapsular femoral-neck fractures. Seventy-eight per cent of the patients were over seventy years of age and 75 per cent had significant medical disabilities as well as the fracture. Forty-two of these patients walked within three weeks of the operation, and thirty-nine were followed for a year or more. The authors stated that there were three postoperative dislocations, no migration of the prostheses, no significant bone absorption, no late complications, and only one instance of postoperative sepsis. Results in eight were rated *excellent*, in fourteen, *good*, and in fifteen, *satisfactory*. The advantages of this type of therapy were given as (1) early ambulation with avoidance of the complications of prolonged bed stay, (2) quick return to preoperative activity, and (3) reduction in total complications with reduced hazard of non-union and aseptic necrosis.

In discussing this paper, Dr. Max A. Levine [10] stated that the authors recommend a radical method of treatment. He pointed out the longest follow-up was one year. He believes that because all previous reviews of long-term follow-up of femoral-head replacement stress the many late complications encountered in using these devices, a conservative attitude should be adopted toward them, and their use limited for salvage.

The Function of the Donor Tissue in Experimental Bone-Graft Operations. Dr. Marshall R. Urist [11], Dr. Norman S. MacDonald [12], and Dr. Jenifer Jowsey [13] reported thirty-two intrametaphyseal bone-graft operations which were performed on the tibia in weanling rabbits. The donor tissue consisted of homogenous bone obtained from rabbits that were previously injected with Ca^{45}, Sr^{90}, and Y^{91}. The donor tissue was collected, refrigerated, and thawed (in the same manner as standard bone-bank bone), and was inserted in a bed of host bone on all sides. Microradiography, micro-autoradiography, microdensitometry, micro-x-ray diffraction, and histochemistry (for cement lines) were used to study the tissues. The results were as follows:

1. The donor tissue was gradually absorbed over a period of sixteen weeks after operation. Radioactivity was retained in the substance of the donor tissue in proportion to the volume of bone that remained at any one interval. Radioactivity was also transferred systemically from the donor to the entire skeleton of the host.

2. The donor tissue became attached to the skeleton by a cement substance consisting of an amorphous condensed layer of mucopolysaccharide produced by the host.

3. Autoradiographs of Sr^{90} labeled bone grafts showed that radioactivity was not transferred locally across the cement line between the donor and the host.

4. Microradiographic and microdensitometric studies showed that there was no hypermineralization of the donor tissue; there was only low-density calcification in new bone, and remodeling of the surrounding old bone of the host bed.

5. The function of the donor tissue was that of a biological catalyst which induced the host to produce new bone yet did not enter into the reaction. This was a physical and surface reaction and it was accomplished before less than one-third of the volume of the transferred tissue was replaced by creeping substitution.

Dr. Kay Holmstrand, a guest from Sweden, corroborated these results and observed from his work with micro-x-ray diffraction that following induction, the hydroxyapatite crystals of the host oriented themselves in the C axis of the crystals of the donor. Similarly the new bone matrix of the host was laid down parallel to the lamellae of the donor as seen by polarization microscopy.

The Flexor Hinge Hand. Dr. Vernon Nickel [14] and Dr. Jacqueline Perry [15] presented a method of restoring partial function to severely deformed or paralyzed hands, based on the hypothesis that the most important single function of the hand is three-point prehension by the pads of the thumb, index, and long fingers.

According to their method, the thumb was fused in a position of opposition. The interphalangeal joints of the two fingers were also fused in the functional position, leaving motion only at the metacarpophalangeal joints of the fingers. Two active muscles were found to provide considerable function, one to open and one to close the jaws of the pincers. The authors said that tendon transfers may be used to supply these activators. This type of hand can also be used with tenodesis of the flexor digitorum profundus tendons if there are strong wrist flexors.

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[12] The Atomic Energy Project, Los Angeles, California.
[13] The Argonne National Laboratory, Lemont, Illinois.
[14] 1700 Brooklyn Avenue, Los Angeles 33, California.
[15] Rancho Los Amigos Hospital, Downey, California.

Excision of the Major Portion of the Calcaneus. Dr. L. L. Wiltse [16], Dr. J. G. Bateman [17], and Dr. Sidney Kase [18] described an operation in which the lower and larger portion of the calcaneus is resected. They reported that a lateral incision was made and the calcaneus cut transversely on a line from the inferior point of the calcaneocuboid joint backward about three-quarters of an inch below the subtalar joint. The lower portion was removed by sharp dissection. The Achilles tendon was sutured to the plantar fascia and the skin was closed loosely. The foot was allowed to drop into equinus position and a pressure dressing applied. A splint was maintained for six weeks and the patient began to walk in eight weeks.

There was complete relief in four patients with chronic osteomyelitis of the calcaneus who were treated by this operation, with cure of osteomyelitis in each. The longest follow-up was ten years.

The authors said that the other indication for the operation is in instances of intractable ulcer on the back of the heel. In two patients operated upon there was cure of the ulcer because of the abundant skin gained by the removal of bone.

The patients were reported to walk remarkably well. The two patients with the longest follow-up have no limp, can stand on tiptoe, are holding regular jobs, are free of pain, and have had no drainage at the operative site.

Dr. Lewis Cozen [19], in his discussion, said that Pridie of Bristol, England, reported excision of fifteen badly fractured calcanei in 1946. At the end of a year thirteen patients were doing well.

A woman underwent excision of the calcaneus for osteomyelitis at the Los Angeles General Hospital in 1947. She complained of moderate pain and the unsightly appearance of her foot. A below-the-knee amputation was done three years later.

The badly comminuted right calcaneus in a man was excised in 1925 and in 1952 the left calcaneus was excised because of severe osteomyelitis. This patient worked regularly despite some discomfort from the callus in the back of the right heel. Surprisingly good function was reported.

End-Result Study in Patellectomy. Dr. Gwilym B. Lewis [20] and Dr. Arthur Holstein [21] reported a total of twenty-seven patellectomies performed in private practice over a period of ten years. Of these, eighteen were elective procedures for chondromalacia and related disorders. Nine were for acute comminuted fracture. The patients ranged in age from fifteen to seventy years, the average being forty-four years. Twenty-one of these knees and four additional knees were evaluated an average of four and one-half years after patellectomy. There were two bilateral patellectomies.

In the subjective evaluation, the question of Scott's R.A.F. (1949) Survey were used. Residual symptomatic and functional complaints averaged 35 per cent less than those in Scott's series. On objective measurement, there was an average 11-degree loss of knee motion, atrophy of the mid-portion and distal portion of the thigh of three-eighths inch, and a five-inch loss of the distance from heel to buttock. Extension against resistance was weak or fair in 35 per cent and strong in 65 per cent of the patients. On roentgenographic examination of eighteen knees, 38 per cent showed variable amounts of calcific deposition in the operative area.

No significant difference in end results was found between the elective and other procedures, or with varied operative technique except that the younger the patient, the better the end result. None of these patients, including a hod carrier and a furniture mover, changed his work because of patellectomy.

The authors concluded that the patella is a functional bone, but that its usefulness is outweighed by the symptoms and disability associated with injuries or pathological conditions affecting the bone.

Dislocations of the Shoulder. With Special Reference to Accompanying Small Fractures. Dr. R. H. Hall [22] and Dr. C. R. Booth [23] discussed a bone contour or notch defect in the posterosuperior area of the humeral anatomical neck which they had demonstrated roentgenographically in patients with acute anterior dislocations, and roentgenographically and at surgery in patients with chronic and recurrent anterior dislocations. The authors said that this defect which is rarely, if ever, visualized in conventional roentgenograms, at times can be demonstrated in some uncertain degree of internal rotation, or it can easily be seen in the manner which they described. Since this defect, when large, may mechanically facilitate recurrent dislocations, it was advised that it should be sought in acute injuries and prevented if possible from becoming permanent. In patients with recurrently dislocating shoulders the authors advised that the defect should be evaluated in planning surgical repair and that it should be repaired when large, just as the labral defect is repaired anteriorly. It was emphasized that the defect should not be confused with normal anatomical variations, and that it is almost invariably traumatic in origin. The technique presented for roentgeno-

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[21] 3011 Telegraph Avenue, Berkeley 5, California.
[22] 1777 Bellflower Boulevard, Long Beach, California.
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graphic demonstration of the notch defect is as follows. The patient lies supine on the table with the base of his hand of the affected extremity on top of the head, the humerus parallel to the body. The x-ray machine is tilted 10 degrees toward the patient's head and aimed at the coracoid process.

Recurrent Dislocation of the Shoulder with Three Operative Failures. Dr. William H. Gulledge [24] and Dr. Thomas B. Dameron, Jr. [25] reported one patient who had had two Putti-Platt repairs followed by a capsular reefing and a bone-block procedure. They felt justified in presenting such a case report since a description of findings at the time of subsequent operation after a failure of Putti-Platt or Bankart type of repair is rare.

The case reported was that of a thirty-year-old man, who had had recurrent dislocation of the right shoulder for a period of one year. At the time of the initial Putti-Platt reparative procedure, a very loose capsule was noted. The preoperative roentgenogram demonstrated a large groove along the outer aspect of the humeral head. A recurrent episode of dislocation of the shoulder occurred one year after this operative repair, followed by several recurrent dislocations with any overhead motion. Two years later when the second Putti-Platt procedure was carried out, the subscapularis tendon was found to be avulsed from its previous humeral attachment. No particular note was made as to the pathological state of the glenoid labrum at the time of either operative procedure. Three months following the second operation the shoulder again began to dislocate with overhead motion. Within six months, the third operative procedure was then carried out; capsular reefing was done at that time. Three months later a dislocation recurred once again. At the time of the final and fourth operative procedure it was noted that the proximal end of the subscapularis had separated from the humeral attachment and had retracted beneath the scapula; the joint capsule was loose and distended and had stripped from the scapular neck. The anterior glenoid rim was smooth and eburnated with no trace of labrum present. A defect in the posterior lateral surface of the head of the humerus was easily demonstrated. Because there was a paucity of soft tissue with which to effect a repair, a bone block taken from the iliac crest was placed in the scapular neck medial to the glenoid rim to increase the effective anteroposterior diameter of the glenoid cavity by one to 1.5 centimeters. It provided a firm buttress anteriorly. With the patient's arm internally rotated, the lateral edge of the capsule together with remnants of the distal aspect of the subscapularis tendon was sutured to the glenoid rim just medial to the graft, and the medial portion of the capsule was plicated over this. Five months postoperatively the patient had regained full motion of the arm, except for limitation of 10 degrees of external rotation. After one year follow-up the patient had had no recurrent dislocations of the right shoulder.

Muscle-Pedicle Bone Graft in Orthopaedic Surgery. Dr. Joe B. Davis [26] presented experimental results in dogs involving cancellous-bone grafts from the iliac crest with an attached muscle pedicle from the tensor fasciae latae in which the bone graft remained viable. In addition, the muscle-pedicle graft in dogs was transferred to soft tissue away from the donor area and incompletely sectioned with an oscillating bone saw to determine its ability to heal. The saw cut in the muscle-fiber pedicle bone graft healed readily, whereas the saw cut in the control bone graft, without blood supply, failed to heal.

This principle was applied by the author in hip-fusion procedures in which the bone graft was removed from the anterior iliac crest with the attached muscle pedicle stemming from the tensor fasciae latae. In arthrodesis of the shoulder joint the bone graft was prepared from the entire acromion, and its pedicle from a portion of the deltoid. In sacro-iliac fusion, the sacro-iliac joint was bridged by a bone graft from the posterior crest of the ilium, the attached pedicle consisting of a portion of glutaeus maximus. A portion of the calcaneus was detached with the short toe extensor for a muscle-pedicle graft in triple arthrodesis. Adaptation of this principle at the lumbosacral joint, however, was not successful. In one instance a two-stage substitution procedure was applied in a patient with non-union of the ulna of long standing. A prepared muscle-pedicle iliac graft was inserted into the ulnar defect with an intramedullary Steinmann pin, utilized for immobilization, and the outer skin surfaces were closed over the operative site. After cast immobilization of four weeks, the skin incision was re-opened and the pelvic-muscle pedicle was severed with successful transfer of the bone graft.

Symposium on the Clavicular Thoracic Region and Its Associated Clinical Problems

The Descent of the Clavicle. Dr. Verne T. Inman [27] discussed the phylogenetic and ontogenetic migration of the shoulder girdle caudad, first by the division of the continuous sheet of muscles in the primitive forms into the levator scapulae and to the serratus anterior. The intervening portion of the muscle has disappeared. The result has been the use of the trapezius as the sole means of support of the shoulder, the contribution of the levator scapulae being minimal.

Ontogenetically, the shoulder girdle descends. At birth, the inner side of the clavicle and manubrium

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are opposite the lower portion of the seventh cervical vertebra, and during puberty migrate caudad, until in the adult they lie opposite the third thoracic vertebra. The clavicle is maintained horizontally through the descent of the scapula and outer end of the clavicle since the fibers of the trapezius are stretched and become more horizontal with the descent.

Descriptive Anatomy of the Claviculothoracic Region. Dr. J. B. deC. M. Saunders [28] demonstrated the special anatomy of the cervico-axillary region and its structure with special reference to costoclavicular syndromes. The special relations of the scalenus complex to the blood vessels and nerves were emphasized. The vulnerability of the structures was shown in relation to various positions of the shoulder, to nutrition, to scoliosis, and to lesions of the vertebral column. The fascia about the brachial plexus and its relation to the coracoid process were discussed. Attention was drawn to the effect of attrition in association with respiration. The vulnerability of the vein to obstruction by an abnormal phrenic nerve, as well as by the clavicle, was illustrated. Arterial constriction due to the median nerve and other causes was commented upon. In conclusion, the necessity of accurate knowledge of the anatomy and physiology of the parts for the diagnosis of the multiple syndromes which occur in this region was illustrated by case histories.

Function and Surgery of the Clavicle. Dr. Donald B. Lucas [29] reported that partial or complete excision of the clavicle is often indicated for (1) acute or chronic instability of the sternoclavicular or acromioclavicular joint, (2) injuries, infections, and tumors of the bone itself, or (3) adequate exposure of the great vessels and nerves at the base of the neck. He said that while the clavicle normally functions as an integral part of the shoulder-joint complex, its absence in no way impairs glenohumeral, scapulohumeral, or scapulothoracic function. Since the clavicle is stabilized by its costoclavicular ligament medially and the coracoclavicular ligaments laterally, proper functioning of the clavicle is dependent upon the integrity of these ligaments, and they determine the sites of election for partial excision of the bone. Excision of the appropriate segment was recommended in the treatment of local dysfunction or disease. Extraperiosteal excision was advised for the adult, to prevent painful and deforming partial recurrence of the bone. Preservation of the omohyoid fascia as an intact layer at the time of surgery was said to protect the underlying vessels and nerves from injury. Removal of the omohyoid fascia permits excellent exposure of the vessels and nerves when desired. Following excision of the clavicle the adjacent borders of the deltoid and trapezius, and the sternocleidomastoid and pectoralis major can be approximated. The cosmetic appearance was reported acceptable and shoulder function unimpaired.

Neurovascular Syndromes of the Claviculothoracic Region. Dr. Rutherford S. Gilfillan [30] discussed the descent of the shoulder girdle from infancy to adulthood and the extreme mobility of the upper extremity in man which may alter the osseous and myofascial relationship in the claviculothoracic zone. Thus, the subclavian and axillary arteries, as well as the brachial plexus, are subject to either compression or tension. The major points of jeopardy to these structures were said to be (1) at the level of the first rib and insertion of the scalenus anterior, (2) between the clavicle and the first rib, and (3) beneath the tendon of the pectoralis minor. In evaluating vascular or neurological changes, examination of these areas was advised. Compression or tension of the neurovascular bundle is known as the scalenus anterior syndrome, the costoclavicular syndrome, and the hyperabduction syndrome. Medical therapy, consisting in shoulder-girdle exercises, was said to be adequate for relief in most cases. However, scaleniotomy, excision of the clavicle, or pectoralis minor tenotomy were advised if necessary.

Benign Bone Tumors of the Vertebral Column in Childhood. Dr. Robert W. Rand [31] and Dr. Carl W. Rand [32] found that among seventy-two instances of intraspinal neoplasm in children there were two examples of hemangioma, one of aneurysmal bone cyst, and three of benign osteoblastoma affecting the vertebral column and the epidural space and producing compression of the spinal cord or cauda equina.

The problems of dealing with hemangioma of the vertebrae were illustrated by the case histories of two patients, both fourteen years of age. One hemangiomatous lesion was noted in the seventh thoracic vertebral body and the other in that of the eighth thoracic vertebra. In one patient laminectomy as well as several courses of deep x-ray therapy amounting to 8,000 roentgens was utilized. The patient recovered full strength in his lower extremities with normal return of sensation in four months, and examination eighteen years later revealed him to be completely well except for a slight thoracic kyphosis. In the second patient, surgery was refused and irradiation alone was utilized. This patient regained only slight movement in her toes. The authors believe, however, that since the benign hemangioma reacts favorably to irradiation, this treatment

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should be tried before surgery, unless the signs and symptoms of spinal-cord compression are advanced or rapidly progressing; in that circumstance, laminectomy should be performed.

The aneurysmal bone cyst occurred in a six-year-old girl. The left lower extremity became paretic. Treatment consisted in surgical exploration of the tumor, when the spinous process, left lamina, and transverse process of the fourth lumbar vertebra were found partially destroyed. As the bone cortex was opened about two ounces of blood came forth under pressure from the anterior part of the tumor. The tumor was partially resected and postoperative x-ray therapy gave subsequent improvement. With respect to the management of this type of lesion, the authors felt that when the tumor is accessible, curettage with or without bone-grafting is indicated. Irradiation was said to be best reserved for inoperable lesions, or those which do not respond satisfactorily to curettage. They stressed that this lesion when located in the vertebral column is essentially benign, but treatment must be early to avoid damage of the spinal cord or cauda equina.

Benign osteoblastoma occurred in patients four and one-half, fourteen, and sixteen years of age. In one, the lesion was localized in the lamina of the twelfth thoracic vertebra with destructive changes. There was positive indentation of the pantopaque as seen on a myelogram on the right side at this vertebral level. In the other patients the tumor was found in the left transverse process of the first thoracic vertebra. The authors said that since these tumors generally grow slowly and do not metastasize, local excision should suffice, although the possibility of recurrence and eventual malignant change must be borne in mind. Subtotal removals were said to be generally followed by recurrence of symptoms and the tumor which may tend to become malignant. Therefore, it was felt that under such circumstances a postoperative course of low-dosage x-ray therapy insufficient to injure the spinal cord should be given.

Dr. Weldon K. Bullock [33], in his discussion, said that this paper is timely in that it points out the response of these rare lesions to conservative therapy. He said that there are 239 tumors from children in the Tumor Tissue Registry of the Los Angeles County Hospital from which one of the cases presented by the authors was obtained. The limiting age of childhood was considered ten years, five years younger than that chosen in this paper. In none of the children was there a vertebral lesion. However, he reported that an osteoid-osteoma of a vertebra occurred in a fifteen-year-old boy. He had seen no child with vertebral hemangioma, but those seen at autopsy did not differ from hemangioma of tubular or irregular bones. In his practice he considers the primary lesion in aneurysmal bone cyst similar to a so-called giant-cell lesion or reparative granuloma of bone in which the vascular process becomes the dominant feature.

Facetectomy without Fusion in the Treatment of Low-Back Pain and Sciatica. Dr. Gerald G. Gill [34] and Dr. Hugh L. White [35] presented a preliminary report of the excision of the posterior vertebral articulations to relieve nerve-root compression in the lumbar spine without spine fusion. They stated that it is generally accepted that there is compression of the fifth lumbar-nerve root in the intraforaminal area of the degenerated or collapsed lumbosacral intervertebral disc secondary to over-riding of the articular facets. The root is impinged upon by the over-riding superior articular facet of the sacrum or by a spur arising from the posterolateral margins of the body of the fifth lumbar vertebra. They pointed out that inasmuch as the facets are believed to be important in the stability of the spine, most authors have stipulated that foraminotomy or excision of the posterior articulations should always be followed by fusion. The authors performed excision of the posterior articulations with removal of the loose lamina in forty-six cases of spondylolisthesis. In only one instance was there definite forward displacement of mild degree which was concomitant with the marked narrowing of the intervertebral disc. Lateral roentgenograms of the lumbar spine made with the patient standing in full flexion and full extension were made by the authors for a number of years to determine stability following articular-facet removal. It was felt to be pertinent that roentgenograms made after excision of the posterior articulations showed that motion in the lower lumbar level in the presence of a narrowed degenerated intervertebral disc was not increased or changed.

Based upon the study of eighteen patients treated for intervertebral-disc degeneration by means of excision of the posterior articulations in the lumbar spine, the authors concluded that (1) the surgical treatment alone does not cause symptoms, since it only rarely allows some degree of forward displacement and does not change the usual motion in the intervertebral articulation; (2) surgery may be carried out and may rather quickly relieve symptoms, thereby obviating fusion, which may be considered later; (3) the myelogram is of limited value in the diagnosis of intraforaminal compression, whereas discography is of great value in showing a laterally herniated intervertebral disc; and (4) excision of the posterior articulations may be necessary in patients with severe scoliosis in whom there are radicular symptoms.

Dr. Merrill C. Mensor [36] in his discussion emphasized that excision of the posterior articulations is of limited use. He said that this operation allows maximum freedom and excursion of nerve roots previously compressed or in danger of compression, but he advised moderate use. He cited Osmond-Clarke's presentation of 1,000 cases of cervical radiculitis in which surgery was performed in less than 4 per cent and felt that a

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similar parallel exists in the low back. He felt that this series of eighteen cases was too small to accept broad and general conclusions and emphasized that in fifteen of the eighteen cases there was definite intervertebral-disc protrusion demonstrable at operation. He agreed with the authors that instability *per se* is not the cause of low-back pain.

Stress Pseudarthroses: The Osteolytic Reaction of Bone to Mechanical Stresses Exceeding Physiological Tolerance. Dr. J. Vernon Luck [37] presented a study of the osteolytic reaction of bone to excessive stresses in patients with fractures of the femoral neck, fractures in long bones, and in those in whom lumbosacral fusion and subtalar bone block had been done, as well as in scoliotic patients treated by spine fusion.

He said that in the fused scoliotic spine the stress reaction occurs at the apex of the primary curve. The cast protecting the fusion area must be not only immobilizing but also corrective in order to minimize the stress reaction. Bone blocks across the articular facets on the concave side of the scoliotic curve may be used so that compression is brought to bear on the fusion block.

That the superior aspect of the femoral neck and the lateral aspect of the femoral shaft are sites of tension stresses when the femur is vertically loaded was pointed out. In contrast, the calcar femorale and the medial aspect of the femoral shaft represent the compression site and, therefore, reflect pressure stresses throughout. The highest tension stress, then, in the femur is at the superior aspect of the femoral neck and the highest pressure stress is on the inferior aspect of the femoral neck. If weight-bearing is allowed a patient with a fracture of the femoral neck which is inadequately healed the callus cannot withstand the mechanical load and stress osteolysis then begins on the tension side, the superior aspect of the neck of the femur.

The author stated that the strength of tubular bone depends on the maintenance of an intact circumference. When this circumference is interrupted by even a small defect the loss of strength is far out of proportion to the loss of bone at the site of the defect. A study of the osteolytic reaction to overloading of a callus bridge in a fracture of a long bone makes us mindful of the necessity to afford these areas adequate protection in order to lower the incidence of pseudarthrosis.

In lumbar and lumbosacral fusion the use of an interspinous compression bone block was reported to hasten fusion. The author believes that a subtalar bone block properly inserted will tend toward the vertical and pressure stresses will predominate. However, if not properly inserted, and the valgus position of the heel is not corrected, it will be a powerful bending force within the graft when weight-bearing is resumed. Under such circumstances there will be clear-cut roentgenographic evidence of solid fusion at the site of the bone block until after resumption of weight-bearing, when the center of the bone block is seen to melt away, thus accounting for stress osteolysis from a bending force in the bone block.

Progress Report: Fibrosarcoma Following a Single Trauma. Dr. Stanley S. Tanz [38] presented a follow-up report of a twenty-six-year-old man in whom after a blow to the left thenar eminence symptoms of left median-nerve irritation developed. The original case was reported at the Western Orthopedic Association Meeting one year ago, when the diagnosis and treatment were discussed. It was implied that, pathologically, this was not a typical case of fibrosarcoma, but was more probably a simple palmar fibromatosis. Local excision was felt to be a more acceptable method of treatment, rather than amputation, which had been performed twenty months after the original injury, through the mid-forearm.

Dr. Tanz confirmed the original diagnosis of fibrosarcoma since pulmonary metastases developed seventeen months after surgery. A right upper lobectomy was performed and the pathological report indicated neoplastic cells more anaplastic than those in the primary lesion.

Western Orthopedic Association Annual Award Resident Essays

Step-Cut Osteotomy with Intramedullary Fixation for Non-Union of Femoral-Shaft Fractures. Dr. Jack L. Lewis [39] presented a survey of the methods of intramedullary fixation for non-union of femoral-shaft fractures, including a review of seventeen patients treated with Küntscher or Hansen-Street intramedullary nailing with supplementary fixation. The procedure consisted in refreshening the opposing bone ends and step-cut osteotomy to increase the approximating surface area and afford increased stability. Autogenous-bone-chip grafting, auxiliary wires or screws at the osteotomy site, and plaster immobilization for varied lengths of time depending on the stability at the time of operation were also used. There was union in twelve and non-union in two patients. Amputation was done in three. The functional results were good when union occurred. The range of hip motion in all patients was good. In those patients in whom union occurred knee motion ranged from 20 to 120 degrees with an average of 68 degrees. Shoe lifts of up to two and one-half inches were required.

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Post-Irradiation Fracture of the Femoral Neck. Dr. William R. Murray [40] described fractures of the femoral neck occurring after irradiation. These fractures were secondary to radiation-induced changes and not to metastatic disease. They were spontaneous, insidious in onset, and preceded either by no trauma or by insignificant trauma. Only those patients who had received radiation therapy for pelvic carcinoma and in whom trauma was not a factor were selected for this series. Fourteen patients were treated for carcinoma of the cervix, one for carcinoma of the uterus, and one for carcinoma of the urinary bladder. All patients with cervical and uterine carcinoma were given both radium and external x-ray therapy. The patient with carcinoma of the urinary bladder received intracavitary cobalt followed by external irradiation. In these cases, as in the majority of reported cases, diagnosis of fracture was preceded by weeks or months of pain and limitation of motion of the involved extremity. In no instance was the onset of pain associated with a single traumatic episode. All fractures visualized were high cervical or subcapital. Diagnosis was dependent upon a spontaneous hip fracture in a patient, in a younger than expected age group, who had received previous irradiation in treatment for pelvic carcinoma. There was slow onset of pain which increased gradually in severity; partial or total relief was obtained by rest. Lateral roentgenograms usually showed the characteristic coxa vara and lack of angulation of the head on the neck. Microscopic examination of specimens taken from the fracture showed premature radiation-induced atrophy of the bone which at the time of fracture was undergoing active repair. Internal fixation, replacement arthroplasty, and resection of the head and neck of the femur were presented as methods of orthopaedic management. Eighteen post-irradiation fractures of the femoral neck occurred in sixteen female patients in a younger age group than that normally expected. The incidence of fracture was 2.1 per cent in patients treated for carcinoma of the cervix by irradiation. The fractures were spontaneous or fatigue fractures occurring approximately twenty-eight months after irradiation. Pathologically there was evidence of bone atrophy, osteoporosis, and active repair. Healing occurred in a high percentage.

Sciatic-Nerve Section in the Paraplegic Spina Bifida Patient. Dr. James P. Dunlap [41] described disturbances of the sympathetic nervous system in the lower extremities in paraplegic spina bifida patients manifested by excessive sweating, coldness, and frequent cyanosis of the limbs. Characteristically surgical wounds healed poorly in these patients because of interference with tissue nutrition. It was pointed out that interruption of the nerve trunks in patients with spina bifida occurs before the sympathetic-nerve fibers join the nerve trunk; therefore the uninterruption of these fibers contributes to the symptoms noted. Normal and abnormal skin temperatures were established. Skin temperatures were recorded before and after injection of fifty cubic centimeters of 1 per cent xylocaine into the sciatic nerve and compared with the normal. The author noted that after blocking of the sciatic nerve in two normal children there was a rise of 18 degrees in the foot. Other skin-temperature comparative observations were made. Histamine scratch tests were carried out on all children studied. In those with spina bifida the areas of skin anaesthesia showed no skin-flare response. The wheal was slow in developing and smaller than normal. The author concluded that the peripheral circulation in a patient with spina bifida could be improved by eliminating the sympathetic supply. In selected patients in whom the lesion was at the level of the fourth lumbar vertebra or lower, this could be done by surgical sectioning of the sciatic nerve. Two patients with spina bifida and paraplegia had deficient circulation in the lower extremities associated with sympathetic vasoconstrictor imbalance. This was remedied by removal of the sympathetic supply through surgical section of the sciatic nerve.

Postoperative Infections in Elective Orthopaedic Surgery. Dr. Bryan M. Shieman [42] conducted a study to determine the relationship of postoperative wound infections to surgical conditions. Rather detailed standardization of controls of investigative methods was presented by the author, who concluded that:

1. Air-borne contamination during surgery is a major factor in surgical wound infection.
2. Three per cent solution of hexachlorophene used in this study was an adequate skin-preparation material.
3. Superficial wound infections, caused by antibiotic-resistant *Staphylococcus aureus*, coagulase positive, which have a tenacious ability to survive, must not be ignored.
4. Surgical wound infections are contingent on multiple factors. Whether or not an infection will occur in a contaminated wound depends on an interplay of local and somatic resistance of the host *versus* the organism and its characteristics. Conditions modifying these factors are: the total time the wound was exposed during surgery, the concentration and type of organisms, infractions of aseptic technique, degree of tissue ischaemia, local and general disease processes, and the efficacy of chemotherapeutic agents.
5. Further investigation in the problem of surgical wound infections is necessary.

Codman's Tumor of the Distal Portion of the Femur with Unusual Clinical Features. Dr.

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JOHN R. BLACK [42] presented a review of the essential features of benign chondroblastoma and chondromyxoid fibroma, emphasizing both the similarity and differential features of the two benign bone tumors. The case report of a fifteen-year-old boy with chondroblastoma obscured by manifestations of joint disease in the knee adjacent to the tumor was presented.

Acute Suppurative Arthritis in Infants and Children. DR. ROBERT L. SAMILSON [44], DR. FRANK A. BERSANI [45], and DR. MELVIN B. WATKINS [46] presented a detailed study of thirty-five cases of acute joint infection in infants and children, bacteriologically proved by joint aspiration and initially uncomplicated by osteomyelitis. These patients were seen from 1934 to 1956 at Columbia-Presbyterian Medical Center in New York City. The authors concluded that incision and drainage is the preferred method of evacuating an acutely infected joint, that early diagnosis is the key to lessening of permanent disability and destruction and determines the outcome. Aspiration or exploratory arthrotomy, particularly in the newborn infant, was considered urgent when the diagnosis is in doubt. Diagnostic aspiration was advised preceding the administration of antibiotics. Although the series was relatively small, the indications are that open incision and drainage yield better results than aspiration and instillation of antibiotics.

In discussion of the paper, DR. DONALD W. BLANCHE [47] concurred with the authors' findings.

Transplantation of Biceps Femoris to Patella. DR. CHARLES L. LOWMAN [48] outlined a method of reconstructive transposition of power from behind to reinforce the knee-extensor mechanism in front. The technique was advocated in order to avoid or reduce the lateral force applied to the patella and to avoid possible development of osteochondritic or arthritic changes. The author said that if rotatory dislocation of the tibia on the femur exists or is threatened, a Yount fasciotomy and capsulotomy should also be done. Success of the procedure should be judged on the basis of the reasons existing at the time of operation (a major one is eliminating a deforming force) and not on whether the knee may be fully extended against gravity. Dr. Lowman feels that the use of biceps alone as a transplant is indicated in most instances.

In his discussion of the paper, DR. EDWIN R. SCHOTTSTAEDT [49] reviewed the cases of sixty poliomyelitic patients with knee-extensor weakness treated by various transplantations about the knee to gain extension. The only patients who could actively extend the knee to 180 degrees were those in whom the combined biceps and semitendinosus transplantations were done. Dr. Schottstaedt felt that Dr. Lowman's attention to details of the technique of transplantation accounted for the good results and the rare incidence of dislocation in his series.

Congenital Dislocation of the Hip. DR. N. J. WILSON [50] and DR. JOHN F. LECOCQ [51] reported a series of 151 congenital dislocations of the hip in 117 patients who were treated in Children's Orthopaedic Hospital, Seattle, Washington. Anatomically, 48.5 per cent of the hips were classified as normal or near normal; functionally 74.2 per cent were so classified. In seventeen hips (11 per cent), normal anatomical results were achieved. The dislocations were treated by closed reduction before the patients were two years old. Only 33.8 per cent of the hips dislocated bilaterally were included in the normal or near normal anatomical classification and the prognosis was poor. No normal and only two near normal results were achieved in patients in whom open reduction was required. In most of these children there was functional impairment with limp, limitation of motion, and pain. Prognosis was also poor in those with prenatal or teratologic dislocations. Preliminary traction appeared to be the best method of obtaining gentle atraumatic reduction. Osteochondritis or aseptic necrosis occurred in sixty-seven hips (44 per cent), in none of which was there a normal anatomical result; in only 34.4 per cent was there a normal functional result.

DR. ELDON G. CHUINARD [52], in discussion, agreed that preliminary traction is important and eliminates the need for adductor tenotomy. In regard to the twenty-three osteotomies done for anteversion, he asked what degree of anteversion was the indication for the operation and whether the procedure rendered the hips stable. He questioned whether osteotomy would have made open reduction unnecessary. He felt that cases reported by him in 1954 indicated clearly that the correction of anteversion contributed to improved results and decreased the necessity for open reduction.

Internal Fixation as an Adjunct to Ankle-Joint Fusion. DR. JAMES W. MILLER [53] presented a

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method of internal fixation of the ankle joint by the use of a single screw passed obliquely through the tibia, the denuded ankle joint, and the posterior portion of the talus. The method was reported successful in a small series of cases. The morbidity was said to be lowered since supplemental bone from the ilium is not necessary and patients are more comfortable in a leg cast.

Dr. Dan H. Levinthal [54], in discussion, reviewed with slides six types of ankle fusion and maintained that the best method of arthrodesis is "that which has given each individual orthopaedic surgeon his best result."

The Ligamentum Nuchae: Clinical Studies. Dr. R. Q. Lewis [55] discussed the short ligamentum nuchae as a factor in the development of neck and shoulder pain. The relationship of congenital shortening of the ligament to the development of degenerative changes in the discs and adjacent vertebrae and joints was noted. Methods of conservative and surgical treatment were outlined and results of surgical wedge resection of the ligament sufficient to restore flexion of the chin to the chest were reported in twelve consecutive cases with highly satisfactory results.

Discoid Medial Meniscus of the Knee Joint Associated with Congenital Relaxation of the Medial Collateral Ligament. Dr. Kirk J. Anderson [56], Dr. John F. LeCocq [51], and Dr. J. Garth Mooney [57] reported a case of discoid medial meniscus of the knee joint of primitive type which was associated with congenital absence of a portion of the tibial collateral ligament with concomitant instability. They noted the rarity of this condition and cited three reported instances. The theory that the meniscus exists in discoid form in the embryo, gradual change in shape taking place until the adult form is obtained, was refuted. Fetal specimens obtained at various periods of development were demonstrated. This fetal material revealed that at no time in the development of the human foetus does the medial or lateral meniscus assume a discoid form. The observations of Dr. E. B. Kaplan were also presented: certain rare individuals are born with the posterior horn of the lateral meniscus unattached to the posterior aspect of the tibial plateau. In such instances, the lateral meniscus is held in place by the meniscofemoral ligament (the ligament of Wrisberg) which forms a link between the posterior horn of the meniscus and the medial condyle of the femur. This ligament is too short to accommodate itself to the normal mechanics of motion of the knee joint. The constant abnormal mediolateral motion of the lateral meniscus in the growing child, therefore, was said to produce secondary enlargement of the meniscus which doubtless had its normal semicircular form at birth. This transformation then leads to a thick fibrocartilaginous mass which assumes a discoid form. Such an explanation appeared pertinent to the case presented, that of a man, twenty-eight years old, in whom a discoid medial meniscus of the primitive type was found responsible for the complaint of aching. There was no history of injury, swelling, clicking, or locking of the knee. The associated instability of the knee was corrected surgically by restoration of normal tension of the medial collateral ligament by transferring the distal attachment to the bone to a lower level on the tibia (Mauck procedure). The superficial long fibers of the medial collateral ligament were very thin, flat, and showed no evidence of past rupture. It was assumed that the abnormal amount of motion in the medial meniscus secondary to congenital relaxation of the medial collateral ligament was pertinent to the observations of Kaplan in reference to the etiology of discoid lateral meniscus.

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Book Reviews

PERIPHERAL NERVE REGENERATION. A FOLLOW-UP STUDY OF 3,656 WORLD WAR II INJURIES. Edited by Barnes Woodhall, M.D., and Gilbert W. Beebe, Ph.D. Washington, United States Government Printing Office, 1956.

Peripheral Nerve Regeneration is a compilation by a number of dedicated neurosurgeons, neurologists, and statisticians who have made a superb effort to draw conclusions from a mass of unwieldy data on peripheral nerve injuries which were treated during and after World War II and the Korean War. As Dr. R. Glen Spurling, Chief Consultant for Neurosurgery during World War II, has said in the Foreword: "It [the book] is a lasting tribute to the foresight and tenacity of the man who conceived this project and brought it to fruition, Dr. Barnes Woodhall, now Professor of Neurosurgery at Duke University School of Medicine and formerly Lieutenant Colonel, Medical Corps, A.U.S."

To the reader who has not been trained in statistics, much of the material in this book is difficult to grasp. This is not, however, a statement of adverse criticism. There are so many intangibles in the evaluation of individual cases that hard and fast judgments cannot be made concerning several phases of the present study of peripheral nerve injuries. For many reasons the statisticians under the co-editorship of Gilbert W. Beebe, Ph.D., have had a most difficult and often frustrating experience in attempting to draw conclusions from the data in their possession.

It seems clear, nevertheless, that the best time to repair a major peripheral nerve is the earliest feasible time short of nineteen days. This fact has been definitely established in connection with the motor components of a nerve; but, strangely enough, the analysis here presented offers no evidence that time between the occurrence of injury and the suturing influenced sensory recovery in any way. One tibial nerve was sutured 380 days after the injury had been incurred and was followed by excellent sensory return. This is most important in its implications with respect to the median nerve where sensation in the hand is of such paramount importance.

The belief held by some neurological surgeons, that primary or emergency suture of major peripheral nerves is the treatment of choice, is proved to be erroneous. As early as 1942, the British had become strongly opposed to primary nerve suture, chiefly on theoretical and experimental grounds. It is interesting to note that the same conclusion is reached in the American study—not on a basis of end results—but because primary nerve sutures were re-explored five times more often than were secondary nerve sutures.

Almost all peripheral nerve surgeons, as well as general surgeons, have feared tension on any suture line. Irrespective of this fact, analysis of nerve sutures carried out in the Zone of the Interior showed that when tension on the suture line was estimated by the operator to be "moderate or greater," there was no demonstrable statistical significance as to the outcome. In a study of early nerve sutures overseas, however, tension noted during the operation and recorded in the operation report appears to have had a significant influence since the chance of re-operation was about four times higher in cases where there was at least moderate tension than it was in cases where no tension existed. Perhaps the surgeons in the Zone of the Interior were more prone to explore nerve sutures which had been carried out overseas; but it is difficult for this reviewer to believe that creating tension on the suture line is not poor surgery if such tension can be precluded by more extensive dissection. By placing tantalum suture material near the ends of sutured nerves, evidence of separation of the nerve ends can be demonstrated roentgenographically. Since separation has been demonstrated fairly frequently by this means, abnormal tension must have played a large part in certain instances of failure.

One of the most surprising and disturbing findings of this study is that "the operator's report on the gross appearance of the nerve ends prior to anastomosis correlated to some extent with that of the neuropathologist and is weakly associated with eventual motor recovery." Again—there are many intangibles in this particular problem—and Dr. Lyons and Dr. Woodhall, in their chapter on Neuropathological Prediction of Recovery, still urge painstaking resection of the nerve ends prior to anastomosis.

When preoperative infection had been present, the results of nerve suture were not as good as when it was not present. Poor results can still be explained on a basis of delay in repair, however; therefore, evidence has not been adduced to demonstrate any specifically deleterious effect which is attributable to infection.

The study of the suture of components of the brachial plexus is most discouraging. Motor and sensory recovery in the hand which can be attributed to suture of a component of the brachial plexus is exceedingly rare. On the contrary, suture of the upper brachial plexus elements carries with it a high probability that useful function of the muscles of the shoulder and upper arm will be restored except in stretch injuries.

The results of nerve suture and simple neurolysis have been compared by the authors of the present text. Although many intangibles appear here, statistical analysis shows that when neurolysis was performed, a "good practical functional" hand resulted twice as often as it did when nerve suture was employed. This clearly points up a lesson learned in World War I: that when a reasonable possibility exists for spontaneous recovery to come about, the operator should not proceed with neurorrhaphy.

An interesting sidelight brought out in this book is that the experience of the operator appeared to have

little relationship to ultimate statistical results. This will shock some neurosurgeons: but the fact remains that the skillful young general surgeon who has had a few months' training in peripheral nerve surgery is often admirably suited for carrying out this type of work.

The present reviewer has said little about the results of nerve suture. These can be found in *Peripheral Nerve Regeneration* for the seven major peripheral nerves in most ample and meticulous detail. As a matter of fact, there is sometimes such a profusion of detail presented for the purpose of avoiding bias that only a minute examination of the text will allow one to comprehend the results fully.

It is surprising how few medical men understand the term *causalgia* in the sense in which S. Weir Mitchell, who coined the word, intended it. Perhaps this should not be too surprising, however, for causalgia is exceedingly rare in civilian life. Excepting Army experience, the present reviewer can recall having seen only two cases since 1926. Anyone who is acquainted with causalgia, and who enters an Army ward can make an immediate diagnosis, at some distance, by observing the agonized facial expression of the patient and the protective attitude he demonstrates toward his injured extremity. Chapter VI by White and Selverstone is a masterpiece of clarity and should settle once and for all the fact that causalgia is a distinct clinical entity and not some vague, though incapacitating, "neuritic pain," or the pain of Sudeck's atrophy.

Knowing the difficulties of the men who compiled this study, the reviewer would not be so presumptuous as to offer any adverse criticism of a substantive nature. He does, however, permit himself to raise a question as to why, in a book of this type, statisticians insist in writing in jargon, and so frequently use stilted English.

Although the style of certain chapters of the book makes for difficult reading at times, it in no way alters the basic soundness and usefulness of so careful and so detailed a study.

Edgar A. Kahn, M.D.

TUMORS OF THE SOFT SOMATIC TISSUES. George T. Pack, M.D., F.A.C.S., and Irving M. Ariel, M.D., F.A.C.S. New York, Paul B. Hoeber, Inc., 1958. $30.00.

There has been a need for a reference work on non-osseous tumors which occur in the extremities and in the non-visceral tissues of the trunk. This book attempts to fill the need and in so doing demonstrates the reason for the absence of a standard work on the subject comparable to those on bone tumors or on tumors of each of the viscera. So many tissues are involved, each with its coterie of tumors, which have different life histories, that it is a very courageous man who would attempt to cover such a wide field.

In their coverage of the subject, the authors extend their comments in many directions and include, besides the tumors, nearly every entity which may be mistaken for a tumor. Thus Dupuytren's contracture has its place in this weighty volume as do keloids, congenital torticollis, and many other non-neoplastic conditions. A scattering of tumors of several viscera are also included with questionable benefit to the organization of the volume. The authors have faced the problems of selection of material by basing the major part of their work on cases seen at the Memorial Hospital and in their private practice, while the recent literature is freely cited and is divided bibliographically according to the chapter headings.

Most of the major clinical problems of the surgery of tumors are faced squarely and the personal opinions of the authors and their concepts and practices are frankly stated. Examples of this frankness may be illustrated by citing the chapters designated "Does a Benign Somatic Tumor Ever Become Malignant?" and "Do Sarcomas . . . Metastasize to Regional Lymph Nodes?".

Fifteen collaborators helped the authors in the preparation of certain chapters. Thirteen of these collaborators and both of the authors are surgeons. The primary approach of this book is surgical rather than pathological or oncological. The lack of intimate collaboration with other specialties is a defect noticeable in a few specific areas, for example, the clinical problems of the amputee and histopathological differential diagnosis. While the book is nominally divided into six sections, five of these are rather short (sixteen to ninety-eight pages), while the major section, "The Treatment of Specific Tumors," is 526 pages long. Each section is divided into chapters which reveal a somewhat unsystematic organization of the material. Some chapter headings are included merely to underline the importance of the subjects they treat, while their extent sometimes is only two or three pages. One would suspect that a good index and specific cross references in the text might eliminate several of the chapters which do not fit into the proper organization of a book such as this.

It is doubtful whether such an extensive handling of the problems of disarticulation and hindquarter or forequarter amputation is properly to be included in a volume such as this, but this is a matter of opinion. Those who refer to this book for specific knowledge on the tumors, which is its strong point, will not be likely to search for details of surgical technique. Those who wish a reference work on surgical technique would probably not look in a book on tumors for these details.

In summary, this is not a definitive work, but it is a valuable book. It includes much material which is generally not available on the shelves of most surgeons' and pathologists' personal libraries. It gives a good summary of most of the information on tumors of the extremities which is now widely scattered in the periodical literature. There are numerous inaccuracies in the handling of subjects which are primarily not the concern of the book, and these inaccuracies become gratuitous sources of annoyance to the reader. The organization of the book could very easily be improved by the elimination of many of the items referred to

and by a closer adherence to the subject at hand. It is hoped that in subsequent editions the authors will do this in order to make this a more definitive reference work.

Jonathan Cohen, M.D.

SURGICAL FORUM, VOL. VIII. Proceedings of The Forum Sessions, Forty-Third Clinical Congress of the American College of Surgeons, October 1957. Edited by the Surgical Forum Committee, Harris B. Shumacker, Jr., *Chairman*. Chicago, The American College of Surgeons, 1958.

This volume is as unusual for its form as for its content. Here are 178 scientific papers presented in 656 pages. These are neither abstracts nor summaries but formal presentations with charts, tables, and other illustrations. The Editor describes them as "briefly recorded." His success in achieving this degree of brevity is worth the study of medical authors and medical editors. In only one respect does the economy of space seem parsimonious. Some of the illustrations suffer from too much reduction in size or scale.

In content these papers reflect the surge of interest in research in every field of surgery. The clinical studies are in the minority.

A study of this closely packed volume will richly repay the reader.

J. A. R.

L'ARTHROGRAPHIE OPAQUE DU GENOU. CONTRIBUTION AU DIAGNOSTIC DES DÉRANGEMENTS INTERNES DU GENOU. Paul Ficat. Paris, Masson & Cie., 1957. 3,800 fr.

In this monograph of 230 pages with 139 unusually fine illustrations the author presents his technique and interpretation of opaque arthrography of the knee joint.

The technique is the author's variant of Lindblom's method (1938) in which ten cubic centimeters of opaque iodine solution is injected intra-articularly. Active motion disseminates the material throughout the knee joint. A compression bandage is applied to obliterate the popliteal space and suprapatellar pouch. In the routine examination ten views are made, two in each of five different positions. Specialized views such as the skyline patellar view are made when indicated. The opaque material is absorbed from the knee joint rapidly leaving no detectable roentgenographic trace. Significant complications were not encountered.

The author thoroughly explores and depicts the anatomy of the normal and pathological knee joint. Although he by no means limits this study to the diagnosis of traumatic lesions of the menisci, he states that it is in this realm that arthrography is of chief value. However, there are illustrations of congenital and traumatic lesions of the menisci, as well as ruptures of cruciate and collateral ligaments and tears of the capsule. Included also are the arthrographic visualization of changes in the hyaline articular cartilage and synovial membrane in arthritis of traumatic, infectious, and degenerative origin, as well as arthrographic identification of intra-articular loose bodies and of tumors of the synovial membrane.

In lieu of giving his own experience with the accuracy of diagnosis in meniscus injuries the author quotes Lindblom (1938) who reported an accuracy of 95 per cent. He neglects, however, to mention Oggoni (1949) who, using the same method, reported an error of 87 per cent. He discusses the errors of diagnosis in only a very general way and fails to mention his estimation of the value of a negative arthrogram in an otherwise difficult problem of differential diagnosis. When the findings of a diagnostic tool are based upon such equivocal criteria that accuracy of diagnosis varies in the hands of two capable men between 95 per cent accuracy and 87 per cent error, it is unlikely that that tool will become popular until a method of reducing the error has been found.

For those who use arthrography of the knee joint as a diagnostic tool or for those wishing to learn to interpret arthrograms of the knee, the large number of unusually fine and meticulously labeled reproductions make this book valuable as an atlas. One has the feeling, however, that it will not make many converts to arthrography of the knee joint.

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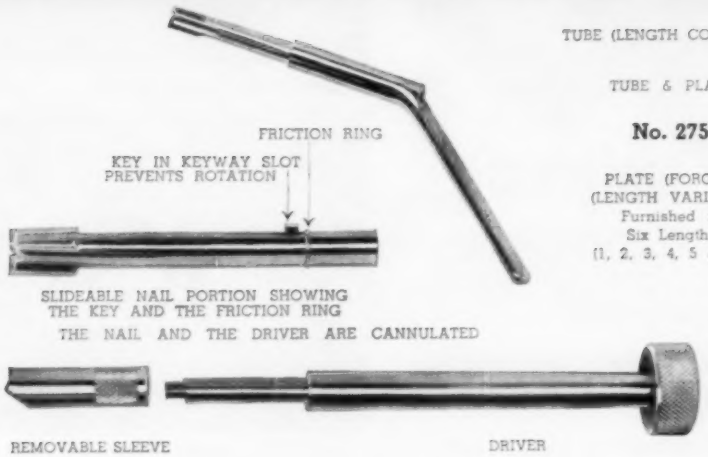

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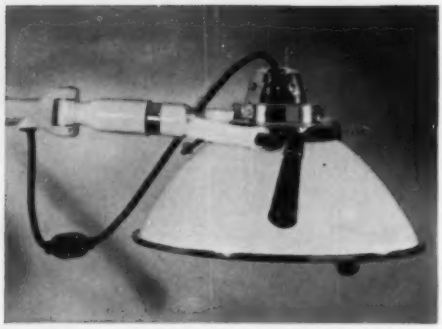

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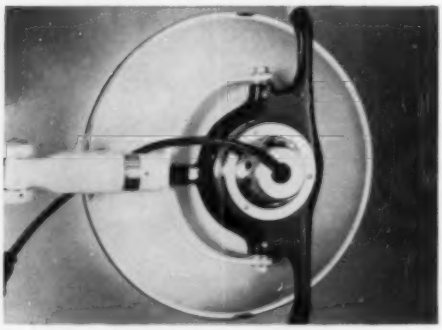

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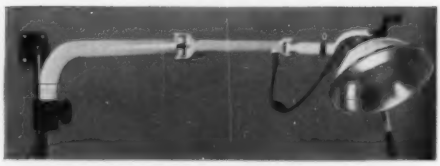

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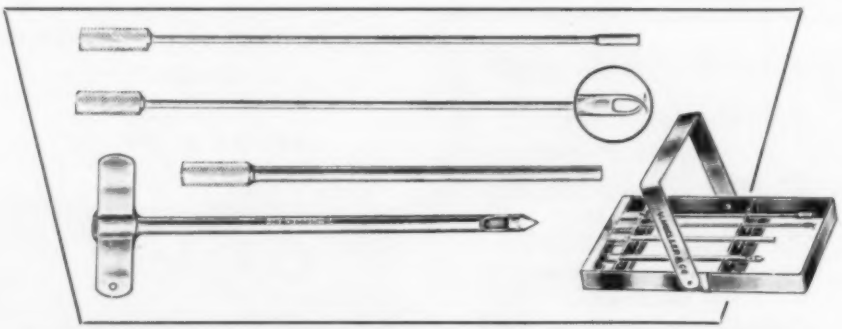

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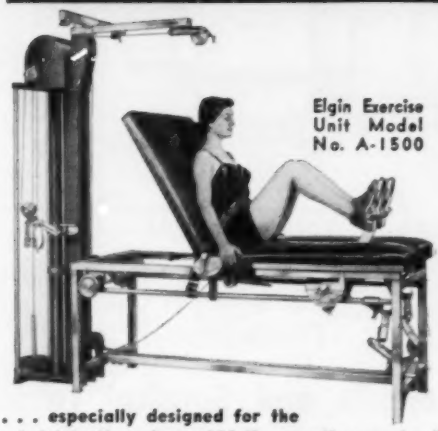

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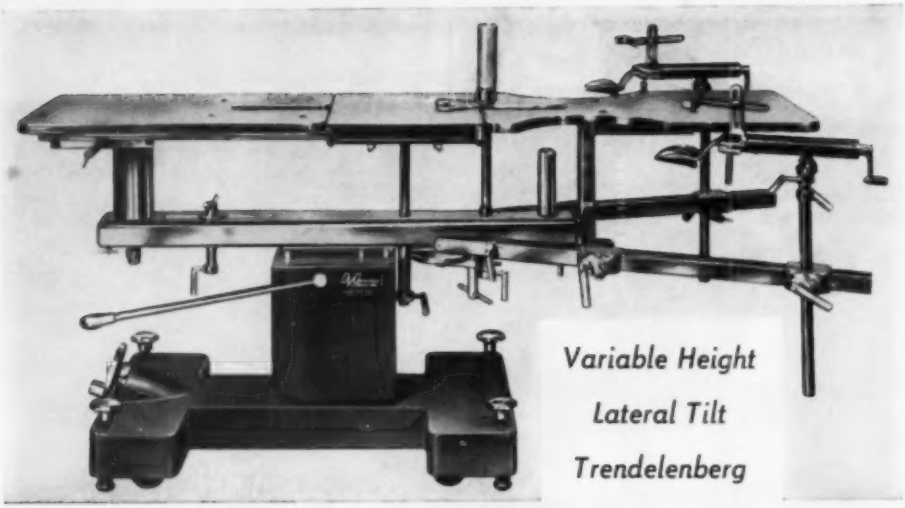

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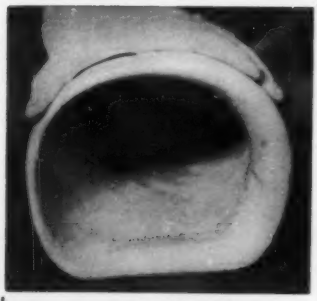

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